S
621.31
E20ced
1974
v.4

DRAFT ENVIRONMENTAL IMPACT STATEMENT ON COLSTRIP ELECTRIC GENERATING UNITS 3 & 4, 500 KILOVOLT TRANSMISSION LINES & ASSOCIATED FACILITIES

VOLUME FOUR TRANSMISSION LINES

ENERGY PLANNING DIVISION, MONTANA STATE DEPARTMENT
OF NATURAL RESOURCES AND CONSERVATION

HELENA, MONTANA 59601

NOVEMBER, 1974

MONTANA STATE LIBRARY
S 621.31 E20ced 1974 c.1 v.4
Draft environmental impact statement on
3 0864 00050253 7

S/621.31/E20ced/1974/Vol.4

Draft EIS on Colstrip Electric Generating Units 3&4, 500 Kilovolt Transmission Lines & Associated Facilities. Volume Four: Transmission Lines.

NOV 26 2003

NRIS # 108

PLEASE RETURN

DRAFT ENVIRONMENTAL IMPACT STATEMENT ON

THE PROPOSED MONTANA POWER COMPANY, PUGET SOUND POWER & LIGHT COMPANY, PORTLAND GENERAL ELECTRIC COMPANY, PACIFIC POWER AND LIGHT COMPANY, AND WASHINGTON WATER POWER COMPANY, COLSTRIP ELECTRIC GENERATING UNITS 3 & 4, 500 KILOVOLT KV TRANSMISSION LINES FROM COLSTRIP TO HOT SPRINGS, MONTANA, AND ASSOCIATED FACILITIES

STATE DOCUMENTS COLLECTION
JUL 14 1980
MONTANA STATE LIBRARY
930 E Lyndale Ave.
Helena, Montana 59601

ENERGY PLANNING DIVISION
ALBERT C. TSAO, ADMINISTRATOR
DEPARTMENT OF NATURAL RESOURCES & CONSERVATION
GARY J. WICKS, DIRECTOR

NOVEMBER, 1974

SUMMARY OF CONTENTS

Volume 1 Summary

Volume 2 Methodology, Need and Alternatives

Chapter One Introduction
Chapter Two Governmental Units Involved
Chapter Three Methodology
Chapter Four The Need for the Proposed Facility
Chapter Five Alternative Electricity Sources
Chapter Six Alternative Coal-Fired Plant Sites
Chapter Seven Power Plant System Alternatives

Volume 3A Power Plant

Chapter Eight Colstrip Project Power Plant Complex
Chapter Nine Coal Mining Activities
Chapter Ten Colstrip Site Inventory and Analysis

Volume 3B Power Plant

Chapter Eleven Colstrip Site Impact Analysis
Chapter Twelve Long-Term Impact Considerations and Information Dissemination

Glossary

Bibliography

Credits and Acknowledgements

Volume 3B Power Plant Appendixes

Volume 4 Transmission Line

Chapter One Introduction and Methodology

Chapter Two Need of the Proposed Transmission Line

Chapter Three Alternative Transmission Technology

Chapter Four Transmission Line Design Criteria and Specification Analysis

Chapter Five Study Area Inventory and Analysis

Chapter Six Study Area Impact Analysis

Chapter Seven Long-Term Impact Considerations and Information Dissemination

Glossary

Bibliography

Appendixes

Credits and Acknowledgements

TABLE OF CONTENTS

Chapter One Introduction and Methodology

- 1.1 Introduction
- 1.2 Methodology

Chapter Two Need for the Proposed Facility

Chapter Three Alternative Transmission Technology

- 3.1 General Discussion
  - 3.1.1 Line Reliability
- 3.2 Alternative Systems of Transmission
  - 3.2.1 Direct Current
    - 3.2.1.1 History
    - 3.2.1.2 D. C. Generation
    - 3.2.1.3 High Voltage D. C. Transmission
    - 3.2.1.4 Future of D. C. Transmission
  - 3.2.2 Alternating Current
    - 3.2.2.1 History
    - 3.2.2.2 A. C. Transmission
  - 3.2.3 Overhead and Underground Transmission
    - 3.2.3.1 D. C. System

        - 3.2.3.2 A. C. System
    - 3.2.4 Summary of Cost Values
        - 3.2.4.1 Expected Technological Development
        - 3.2.4.2 Changes Expected in Three Years
        - 3.2.4.3 Changes Expected in Five Years
        - 3.2.4.4 Changes Expected in 10 Years
        - 3.2.4.5 Changes Expected in 20 Years
- 3.3 Existing Transmission Systems
    - 3.3.1 Montana Transmission Grid System
    - 3.3.2 Northwest Grid System
    - 3.3.3 Western Transmission Grid System
- 3.4 Engineering Alternatives for Colstrip Project
    - 3.4.1 General Discussion
        - 3.4.1.1 Power Delivery Point
        - 3.4.1.2 Criteria for Colstrip Transmission Line Reliability
    - 3.4.2 Alternative Routes
- 3.5 Optimum Technology Selection

Chapter Four Transmission Line Design Criteria and Specification Analysis

- 4.1 Design Criteria
- 4.2 Physical Characteristics of the Proposed System
    - 4.2.1 Right-of-Way and Conductors
        - 4.2.1.1 Right-of-Way Width
        - 4.2.1.2 Conductors
    - 4.2.2 Tower Body and Foundation
    - 4.2.3 Substations
- 4.3 Construction and Maintenance
    - 4.3.1 General Description
        - 4.3.1.1 Construction
        - 4.3.1.2 Maintenance
- 4.4 Electrical Characteristics of the Proposed System
    - 4.4.1 Corona Effect
        - 4.4.1.1 Audible Noise
    - 4.4.2 Radio and Television Interference
        - 4.4.2.1 Radio Frequency Interference (RFI)
        - 4.4.2.2 Television Interference (TVI)
    - 4.4.3 Electrostatic and Electromagnetic Induction
        - 4.4.3.1 Mutual Inductive Coupling

4.4.3.2 Capacitive Coupling

4.4.4 Electrochemical Reaction

Chapter Five Study Area Analysis and Inventory

5.1 Natural Environment

5.1.1 Geology

5.1.1.1 Physiography

5.1.1.2 Other Geologic Parameters

5.1.1.3 Seismicity

5.1.2 Hydrology

5.1.2.1 Surface Water

5.1.2.2 Groundwater

5.1.3 Soil

5.1.3.1 Parameters to be Assessed

5.1.3.2 Existing Available Data

5.1.3.3 Data Interpretation

5.1.4 Vegetation

5.1.4.1 Existing Vegetation Types

5.1.4.2 Relict Areas

5.1.4.3 Forest Resources

5.1.4.4 Range Resource

- 5.1.4.5 Poisonous and Noxious Plants
- 5.1.5 Wildlife and Fisheries
  - 5.1.5.1 Mammals
  - 5.1.5.2 Birds
  - 5.1.5.3 Fisheries
- 5.1.6 Meteorology
- 5.2 Cultural Environment
  - 5.2.1 Existing Land Use
    - 5.2.1.1 Land Use Categorization
  - 5.2.2 Proposed/Potential Land Use
    - 5.2.2.1 Land Use Categorization
  - 5.2.3 Land Ownership
    - 5.2.3.1 Data Sources and Data Collection
  - 5.2.4 Population, Social and Economic Factors
    - 5.2.4.1 Population
    - 5.2.4.2 Social Organization
    - 5.2.4.3 Social Services
    - 5.2.4.4 Economic Factors

Chapter Six Impact Analysis
- 6.1 Natural Environment

6.1.1 Impacts on Geology
    6.1.1.1 Physiography
    6.1.1.2 Other Geologic Impacts
6.1.2 Impacts on Hydrology
    6.1.2.1 Surface Water
    6.1.2.2 Groundwater
6.1.3 Impacts on Soil
    6.1.3.1 Construction Related Impacts
    6.1.3.2 Operation Related Impacts
    6.1.3.3 Maintenance
    6.1.3.4 Reclamation
    6.1.3.5 Impacts of Significance in Corridor Selection
    6.1.3.6 Sediment Risk Map Ratings Defined
6.1.4 Impacts on Vegetation
    6.1.4.1 Construction Phase
    6.1.4.2 Operation
    6.1.4.3 Maintenance
6.1.5 Impacts on Wildlife and Fisheries
    6.1.5.1 Construction Period

        - 6.1.5.2 Positive Effects
        - 6.1.5.3 General Avoidance Reactions
        - 6.1.5.4 Operational Impacts
        - 6.1.5.5 Collisions
        - 6.1.5.6 Other Impacts
        - 6.1.5.7 Negative Effects of Wildlife on Transmission Lines
    - 6.1.6 Impacts on Meteorology
        - 6.1.6.1 Construction
        - 6.1.6.2 Operation
- 6.2 Cultural Environment
    - 6.2.1 Impacts on Existing Land Use
        - 6.2.1.1 Agricultural Land Uses
        - 6.2.1.2 Urban Land Uses
        - 6.2.1.3 Recreation
        - 6.2.1.4 Archaeologic and Historic Sites
        - 6.2.1.5 Aesthetic Impacts
    - 6.2.2 Proposed and Potential Land Use
    - 6.2.3 Impacts on Population and Social Factors

            6.2.3.1 Population
            6.2.3.2 Impact on Social Organization and Life Styles
            6.2.3.3 Impacts on Social Services
            6.2.3.4 Summary
        6.2.4 Economic Impacts
    6.3 Impacts of Alternate Corridors
    6.4 Recommended Procedures to Minimize Impacts
        6.4.1 Construction
            6.4.1.1 Survey
            6.4.1.2 Clearing
            6.4.1.3 Road Construction
            6.4.1.4 Tower Erection
            6.4.1.5 Conductor Stringing
            6.4.1.6 Final Clean Up and Restoration
        6.4.2 Maintenance
        6.4.3 General
Chapter Seven Long-Term Impact Considerations and Information Dissemination
    7.1 Adverse Impacts Which Cannot Be Avoided
        7.1.1 Aesthetic Impacts
        7.1.2 Land Use Changes

    - 7.1.3 Use of Natural Resources
- 7.2 Irreversible and Irretrievable Commitment of Resources
    - 7.2.1 Energy
    - 7.2.2 Non-Renewable Resources
    - 7.2.3 Timberland Agricultural Products Lost
- 7.3 Long-Term Considerations of the Proposed Colstrip Project
    - 7.3.1 Montana Considerations
    - 7.3.2 National and Global Considerations
- 7.4 Public Involvement

Glossary

Bibliography

Appendixes (see following table)

Credit and Acknowledgements

Table of Appendixes

Appendix I: Electrical Systems

- I1: Power System Stability
- I2: Circuit Breakers (CB)
- I3: Superconductivity
- I4: Performance Capabilities and Parameters of 2000 MCM Paper-Insulated Oil-Pipe-Type Cable Systems Summer Ratings
- I5: Reserve Margins for Northwest Power Pool Systems
- I6: Worst Case Calculations

Appendix J: General Soils Map

Appendix K: Geology

- K1: Historic Geology
- K2: Structure
- K3: Stratigraphy and Igneous Rocks
- K4: Economic Geology

Appendix L: Vegetation

- L1: Vegetation Species List
- L2: Environmental Relationships of Vegetation Types Within the Study Area

Appendix M: Land Use

CHAPTER ONE Introduction and Methodology

1.1. Introduction

The proposed transmission system would extend approximately 430 miles across Montana from Colstrip to Hot Springs and would consist of two single-circuit 500 KV lines in a 300-foot right-of-way. One new line would be constructed from Colstrip to Hot Springs. The other line would be created by converting a proposed double-circuit 230 KV line (not yet constructed) from Colstrip to Billings to 500 KV capacity, and constructing a second new 500 KV line from Billings to Hot Springs to connect to the converted 230 KV line.

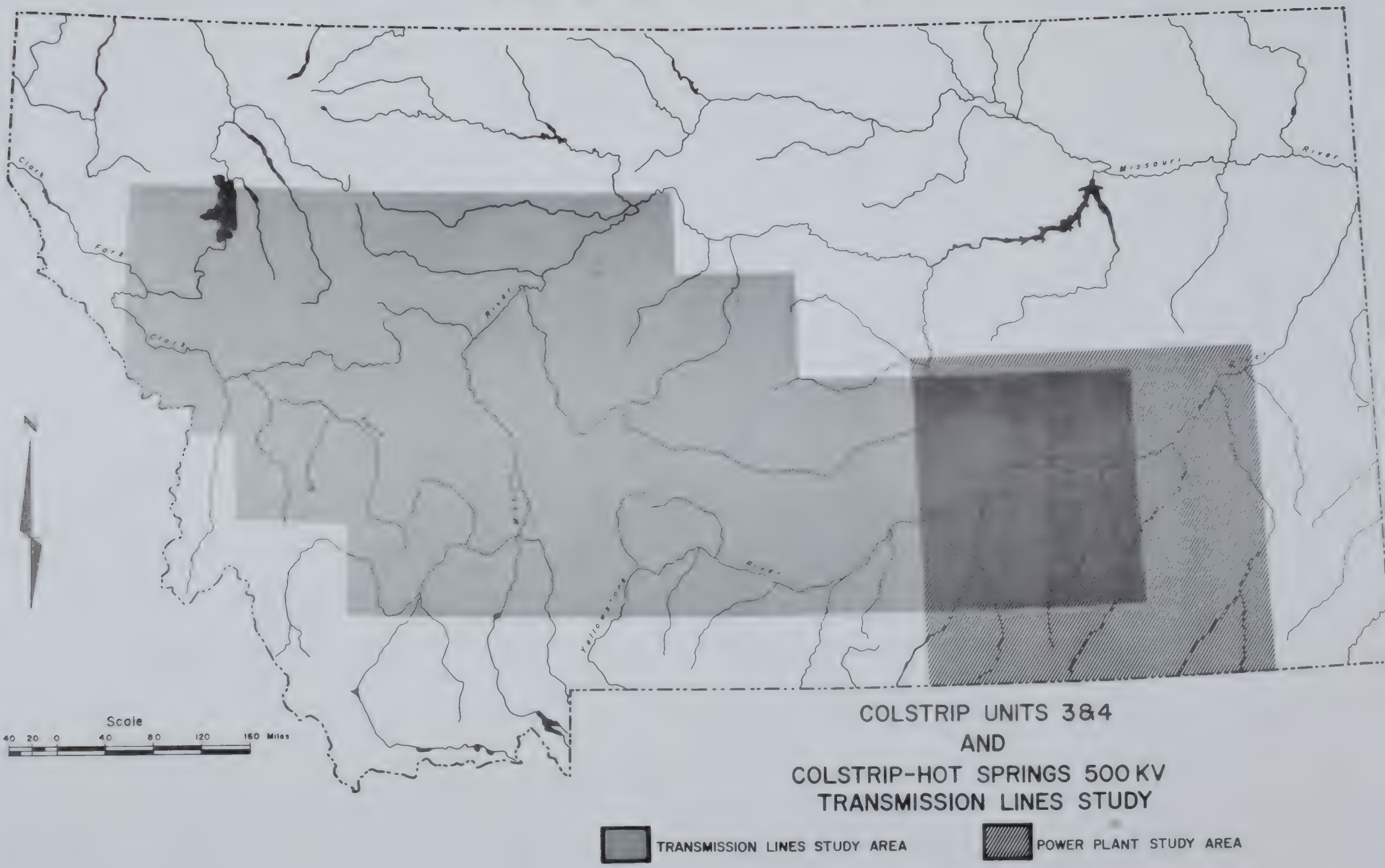
The following chapters contain an analysis of the transmission system and its components as well as an inventory and impact analysis of the natural and cultural environment which would be affected by the lines. A geographic area large enough to include all reasonable routes for the proposed lines between Colstrip and Hot Springs was chosen for the study area. This area, covering approximately ½ of Montana, is shown on the locator map included in this section. The area includes all or parts of Rosebud, Treasure, Big Horn, Prairie, Yellowstone, Musselshell, Powder River, Carbon, Stillwater, Petroleum, Fergus, Golden Valley, Stillwater, Sweet Grass, Wheatland, Judith Basin, Park, Gallatin, Meagher, Cascade, Choteau, Teton, Pondera, Broadwater, Madison, Jefferson, Silver Bow, Deer Lodge, Powell, Granite, Ravalli, Missoula, Lewis and Clark, Flathead, Lake, Saunders and Mineral counties.

It should be noted that the power plant analysis compares the proposed Colstrip location with other possible alternative sites and/or means of supplying a need for electrical energy in the Northwest. However, this analysis of the transmission system assumes a generation point at Colstrip and an end or receiving point for the transmitted power at Hot Springs.

1.2. Methodology

In this study a typical EIS process (which primarily includes analysis of impacts) rather than a planning procedure (which is used for decision-making) has been employed to evaluate the corridor impact of the proposed Colstrip to Hot Springs 500 KV lines. However, planning procedure has been used for the analysis of need and alternatives for the lines to insure that these strategy related decisions (corridor selection considered a tactical related decision) of the applicants are thoroughly examined. For corridor selection, emphasis has been placed on the construction and design criteria of the proposed lines, and the theoretical impact of the lines. The planning process will be used later to select

STATE OF MONTANA



COLSTRIP UNITS 3&4
AND
COLSTRIP-HOT SPRINGS 500 KV
TRANSMISSION LINES STUDY

an optimum corridor. Comparisons will be made between this optimum corridor and the applicants' preferred corridor. All of this material will be published in the final environmental impact statement on this project.

The method of transmission corridor study uses a systematic planning process to meet the decision-making requirement. The accompanying diagram (Figure 1-1) entitled "Transmission Corridor Study Methodology" offers an overview of the approach. This methodology provides a measure of organizing and simultaneously directing and executing a complex series of separate, but interrelated, social, economic, environmental and engineering studies. Due to the dynamic nature of the methodology, some processes are conducted in hierarchial order while others are carried out concurrently in order to improve efficiency. Certain processes shall be conducted in hierarchial order because the results of prior processes will dominate the research direction of following processes. The initiation and study of a given process without the required previous step results in wasted work or erroneous findings. For example, if the inventory of environmental elements is initiated before the need of the proposed facility can be established, the inventory may later be proven unnecessary if the need is found unjustifiable. However, in certain cases, special measures can be used to avoid the above described situation. These special measures have to be generated on a case by case basis.

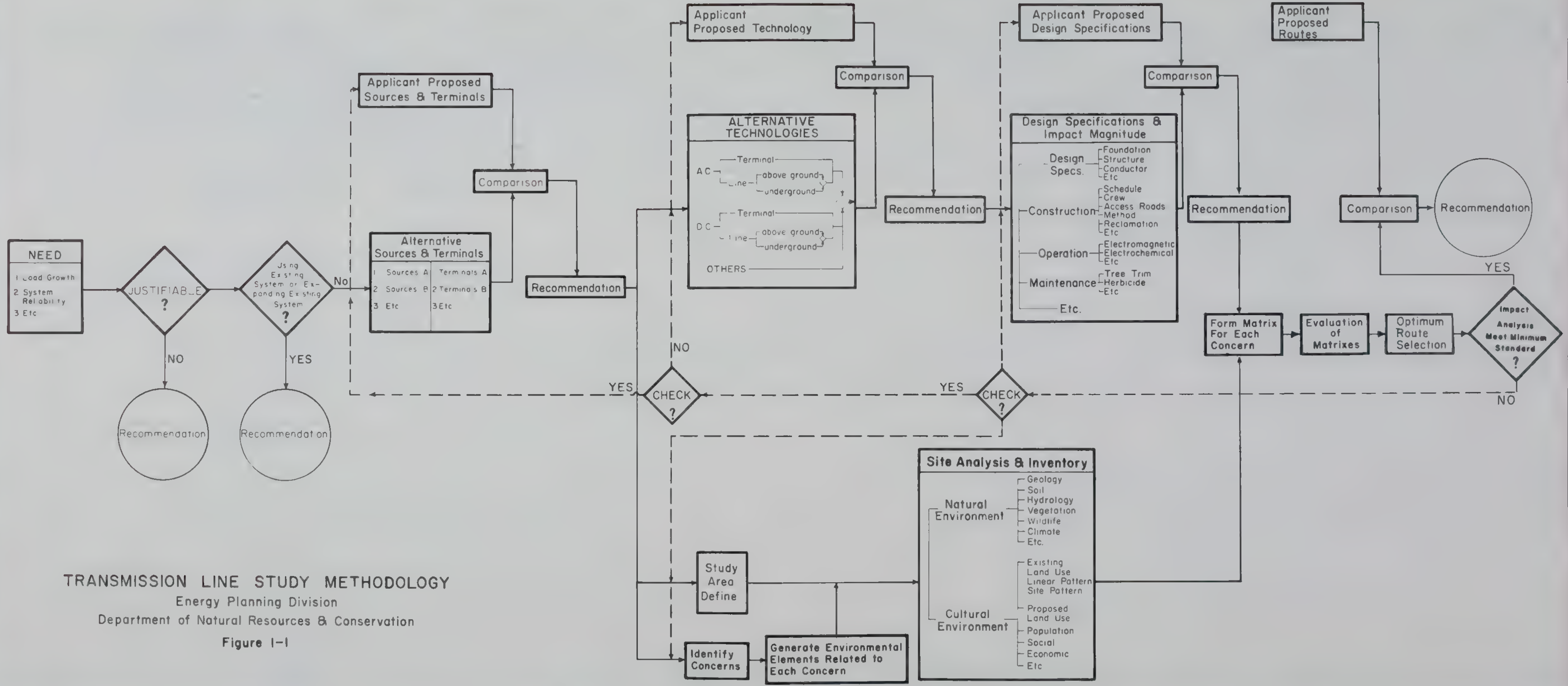
A detailed explanation of each process of the methodology shown in the diagram is as follows:

A. Justification of the Need

In general, the need of a transmission line arises if one or both of the following situations exist:

1. Supply the load growth requirement.

   Due to the electricity consumption growth of an area, a transmission line(s) is required to transmit electricity from a source which can be either a generation plant or a substation to the load center or the existing transmission system(s) through a substation. In this case, the study of the area load growth becomes a prerequisite. The conventional method of studying load growth is based on the historical growth rate of an area with an adjustment made to incorporate the special, known facts that likely will effect future growth. For a large, complex region, an economic simulation model based on selected parameters has been used. Although this simulation model may give accurate predictions, the worthiness of trading-off years of model development, contract monitoring and periodic updating still remain to be proven.



TRANSMISSION LINE STUDY METHODOLOGY
Energy Planning Division
Department of Natural Resources & Conservation
Figure I-1

PLEASE RETURN

2. Increase reliability

In order to insure a constant supply of electricity to a load center, a transmission system should be capable of absorbing certain degrees of line outage. If this requirement cannot be met by an existing system, an extra transmission line(s) may be needed.

B. Utilization or Expansion of Existing Systems To Accommodate the Need

If the need is established, the next step is to decide upon measures to serve the need. Prior to constructing a new transmission line, the existing system shall be examined in order to conclude whether or not it can be expanded to accommodate the need. Examples of ways to expand the existing system include replacing conductors and replacing both tower or pole structures and conductors. The latter, in some cases, might require widening of the right-of-way. In general, expansion of the existing system results in less environmental impacts, but not necessarily less cost.

C. Determination of Electricity Sources and Terminals (i.e. system alternatives)

If expansion of the existing system is not feasible, construction of a new transmission line is necessary. Therefore, alternative electricity sources, terminals, and intermediate terminals (if any) must be established and a comparison made based on installation cost, engineering and environmental impacts (including natural, land use, social and economic elements) in order to select an optimum source and terminals.

Intermediate terminals, in general, are uses to 1) supply more remote (distant) future load growth of an intermediate-terminal-related area as compared to the need of the proposed project; or 2) increase the reliability of the intermediate-terminal-located area in order to minimize total long-range impacts on the environment. The disadvantage of this intermediate terminal may be increased costs due to the detour caused by connection of the source point with the terminal through the intermediate point.

Without determining the optimum source and terminal, the next process of defining the study area and conducting the environmental inventory may later be void. This and all successive steps of the methodology can be grouped into two major categories: engineering design related and environmental related. All engineering steps are intimately related and affected by each other. Any change made within a step may trigger a change of design for all the other steps. For example, a change of electricity source may result in using D.C. transmission rather than A.C., which in return demands different design specifications. Also, close interrelationships exist betwen engineering and environmental steps. For example, in order to minimize the impacts on the environment to meet certain required standards, certain engineering design features may have to be changed. On the other hand, a change in engineering design specifications may involve different impacts on the environment. As a result of these inter-and intra-relationships, check-back loops are employed in the methodology to ensure that all the relationships are considered. Only the most important loops are indicated on the diagram.

D. Transmission Technology Selection

After the electricity source and terminals have been determined, two series of steps, one engineering related and the other environmental related, can be conducted concurrently.

Various transmission technologies include various voltages of A.C. and D.C. and above ground and underground transmission. Conventially, the selection of technology has been based solely on the installation cost. D.C. lines are used for long distance, direct transmission of large amounts of power without any intermediate terminals. Underground transmission is only applied to lower voltage lines. Comparisons shall be made based on factors of installation cost, engineering and impacts on the environment in order to select an optimum technology. Additionally, government and industry shall allocate adequate funds for extensive research in D.C. and underground transmission (including means of reducing installation costs, such as D.C. terminals and superconductivity) due to their potential for minimizing environmental impacts.

E. Transmission Corridor Selection

In order to select the transmission corridor, sub-processes are developed as follows:

1. Determination and analysis of engineering design criteria/specification and impact magnitude

   Transmission line characteristics that are considered for corridor selection are as follows:

   a. Various construction methods and related impact magnitudes of the following items:

      i. Right-of-way clearance

      ii. Temporary and permanent access roads

      iii. Staging sites

      iv. Foundation digging

      v. Tower erection

      vi. Conductor stringing

      vii. Constuction crew

viii. Construction camp site (if any)

b. Physical presence of the lines

  i. Right-of-way

  ii. Self-supporting towers

  iii. Guyed wire towers

c. Operational characteristics and magnitude.

  i. Electrostatic effects

  ii. Electrochemical reactions

  iii. Electromagnetic effects
    Radio interference
    TV interference
    Other communication related interference

  iv. Audible noise

  v. Heat

d. Maintenance

  i. Regular maintenance

  ii. Emergency maintenance

Various construction method and design characteristics have different impacts on the environment. On the other hand, various mitigated measures can be used to limit construction impacts or to specify the design in order to minimize impact. Therefore, the construction methods and design of the transmission lines shall continuously interact with the corridor selection process and its related impact until a final corridor is delineated.

2. Identify concerns (i.e., under what conditions or criteria shall a transmission corridor be selected?)

Criteria used for corridor selection vary from region to region depending upon the characteristics of the natural and cultural environment of the area studied. A set of criteria has been generated for the study of these 500 KV lines as follows. A selected transmission corridor shall have:

  i. Least impact on natural ecological systems including least impact on vegetation system, wildlife system, hydrological system and least soil erosion.

  ii. Least impact on existing human settlement which includes least physical intrusion to dwelling areas, least TV and radio interferences, etc.

iii. Least installation and maintenance cost, including least cost of land acquisition, least material and construction costs, and least maintenance cost.

iv. Least impact on agricultural production, including least impact on dry crop farming, irrigated land and ranching operations.

v. Least impact on forestry production

vi. Least impact on recreation activity

vii. Least visual impact

viii. Least impact on future land use

ix. Greatest line reliability

x. Maximum utilization of existing rights-of-way

During the process of identifying concerns, it is essential to make sure that the magnitude of each concern stays at relatively the same scale, i.e. scale homogeneity exists between concerns. Possible overlap between the content of each concern should be avoided.

An optimum corridor usually can be generated to fulfill each concern, however, due to the conflicting nature of some concerns, an optimum corridor for one concern may be unacceptable for another. "Trade-offs" between concerns will be discussed later.

3. Identify environmental elements that shall be used for optimum corridor selection for each concern.

A set of environmental elements is needed in order to select a corridor that will fulfill the requirement of each concern. For example, to define a corridor with least impact on the wildlife system, determination of wildlife habitat by species, and key areas including wintering ground, migration routes, etc. should be made. This is a lengthy and continuous process. Prudence and patience must be exercised to carry out the process correctly.

It is self-evident that for each concern various individuals of different disciplinary expertise are needed in order to indentify the list of environmental elements.

4. Site analysis and inventory

Typical methods of inventorying environmental elements include searching for existing available data, remote sensing interpretation, and field surveys. After data inventory, it is necessary to store the data into digital format for efficient data retrieval and manipulation. This may be done by either a grid system (dominant cell or perientile cell) or a polygon system.

5. Matrix formation and rating

For each concern listed in Section E2 above, a matrix can be formed as shown in Figure 1-2, with all tranmsission line characteristics described in Section E1 listed in the Y-axis and environmental elements listed on the X-axis. To select an optimum corridor for each concern, related environmental elements are compared to each other on the basis of suitability for corridor location. Then a rating system is used to define the various categories of comparative suitability. An example of a rating system is as follows:

Very unsuitable
Unsuitable
Moderately unsuitable
Moderately suitable
Suitable
Very suitable
No relation
(Suitability unknown)

An example of a rated matrix is given in Figure 1-3.

6. Final corridor selection

Final corridor selection results from comparisons made between concerns. These comparisons involve different issues. Certain concerns contain dollar values only, while some imply quantifiable values, and others relate to abstract values. In general, no single corridor can fulfill all concerns, but the possibility of finding one should not be ruled out. Therefore, in the first comparison all unsuitable values of all concerns should be combined, and a possible corridor may be revealed. Otherwise, subjectivity must be employed, although certain guidelines for minimizing impacts can be used. Therefore, various patterns of comparison between concerns ought to be tested in order to obtain a final corridor.

Corridor selection through compari-

TRANSMISSION CORRIDOR STUDY MATRIX

Model Type ________________

Rating Categories
6 = Very Compatible
5 = Compatible
4 = Moderate Compatible
3 = Moderate Incompatible
2 = Incompatible
1 = Very Incompatible
0 = No Relation

Natural Elements
- [illegible]
- Physiography
  - [illegible]
  - [illegible]
  - [illegible]
  - [illegible]
  - Mountain - 1
  - Mountain - 2
  - Mountain - 3
  - Mountain - 4
  - Mountain - 5
  - Foothill - 1
  - Foothill - 2
  - Foothill - 3
  - Foothill - 4
  - Basin - 1
  - Basin - 2
  - Plains - 1
  - Plains - 2
  - Plains - 3
  - Plains - 4
  - Plains - 5
  - Plains - 6
  - Alluvial - 1
  - Alluvial - 2
- Hydrology
  - Lakes & Reservoirs
  - Stream
    - Major
    - Minor
    - Intermittent
- Sediment Risk
  - Severe
  - Moderate
  - Slight
- Vegetation
  - Vegetation Types
    - Subalpine
    - Lodgepole Pine
    - Spruce - Fir
    - Western Larch
    - Douglas Fir
    - Western Ponderosa Pine
    - Eastern Ponderosa Pine
    - Ponderosa Pine Savannah
    - Limber Pine - Juniper
    - Juniper Complex
    - Cottonwood-Willow-Dogwood
    - Cottonwood-Willow
    - Boxelder-Green Ash-Rose-Chokecherry
    - Big Sagebrush-Bluebunch Wheatgrass
    - Big Sagebrush-Western Wheatgrass
    - Big Sagebrush-Western Wheatgrass-Grama
    - Big Sagebrush-Western Wheatgrass-Needle and Thread-Grama
    - Big Sagebrush Grass
    - Silver Sagebrush-Greasewood
    - Alpine
    - Bluebunch Wheatgrass-Fescue
    - Bluebunch Wheatgrass-Needle and Thread
    - Western Wheatgrass-Needle and Thread-Green Needlegrass
    - Western Wheatgrass-Needle and Thread-Grama
    - Needle and Thread-Western Wheatgrass-Grama
    - Needle and Thread-Sand Dropseed
    - Grama-Needle and Thread
    - Near Pristine Vegetation
  - Timber Size
    - Greater than 9" d.b.h.
    - 9"-5" d.b.h.
    - Less than 5" d.b.h.
    - Damaged Stand
  - Stocking
    - Well Stocked
    - Medium Stocked
    - Poor Stocked
- Wildlife
  - Mammals
    - General Distribution
      - Elk
      - Whitetail Deer
      - Pronghorn Antelope
      - Mountain Goat
      - Bighorn Sheep
      - Moose
    - Critical Areas
      - Elk
      - Mule Deer
      - Whitetail Deer
      - Pronghorn Antelope
      - Mountain Goat
      - Bighorn Sheep
      - Moose
  - Birds
    - Ring Necked Pheasant-General Distribution
    - Merriam's Turkey-General Distribution
    - Waterfowl-Breeding Areas
    - Sage Grouse-Wintering Area
    - Sage Grouse-Strutting Ground
    - Sharptail Grouse-Wintering Area
    - Sharptail Grouse-Dancing Ground

Cultural Elements
- Specially Managed Areas
  - Wilderness Area
  - Primitive Area
  - New Study Area (U.S.F.S.)
  - Proposed Study Area (Montana)
  - Nonselected Roadless Areas
  - National Wildlife Refuges and Ranges
  - Game Management Areas
  - Wild & Scenic Study Rivers
  - Potential Wild & Scenic Study Rivers
  - Square Butte Natural Area
  - Municipal Watersheds
  - Snow Survey Stations
- Existing Land Use
  - Urban Areas
  - Small Communities
  - Scattered Built-up Areas
  - Industrial Areas
  - Industrial Sites
  - Irrigated Land
  - Dry Crop Land
  - Commercial Woodland
  - Non-Commercial Woodland
  - Rangeland
    - Range Types
      - Grassland
      - Sagebrush
      - Timber Range
      - Broad leaf
      - Barren (Badland)
    - Range Conditions
      - Excellent
      - Good
      - Fair
      - Poor
      - Very Poor
  - Transportation
    - Railroads
    - Highway
      - Freeway
      - Paved Highway
      - Graveled
      - Unsurfaced
      - Primitive
    - Airport
      - Public Large
      - Public Small
      - Private
  - Utility
    - Power Plant
      - Hydro Plant
      - Thermal Plant
    - Substation
    - Electric Transmission Lines
      - 500 KV
      - 230 KV
      - 161 KV
      - 115 KV
      - 100 KV
      - 69 KV
      - 57 KV
      - 50 KV
      - 34.5 KV
    - Gas Pipeline
    - Oil Pipeline
    - Refined Products Pipeline
    - Refinery
  - Communication
    - TV Station
    - Radio Station
    - TV Signal Strength
      - Grade A
      - Grade B
    - Radio Signal Strength
      - Primary Coverage
      - Secondary Coverage
  - Recreation
    - State Park
    - County City Park
    - Campground
    - Other Terrestrial Related Activities - Natural Environment Oriented
    - Other Terrestrail Related Activities - Cultural Environment Oriented
    - Other Water Related Activities
    - Point of Interest
    - Scenic Roadway
    - National Register Historic Site
    - Other Historic Site
    - Archaeological Site
- Potential Land Use (Partial)
  - Potential Irrigable Land
  - Potential Recreation Land
- Loc. Community Serv. Capacity
  - High
  - Medium
  - Low
- Local Community Social Structure
- Local Community Economic Structure

Transmission Line Characteristics

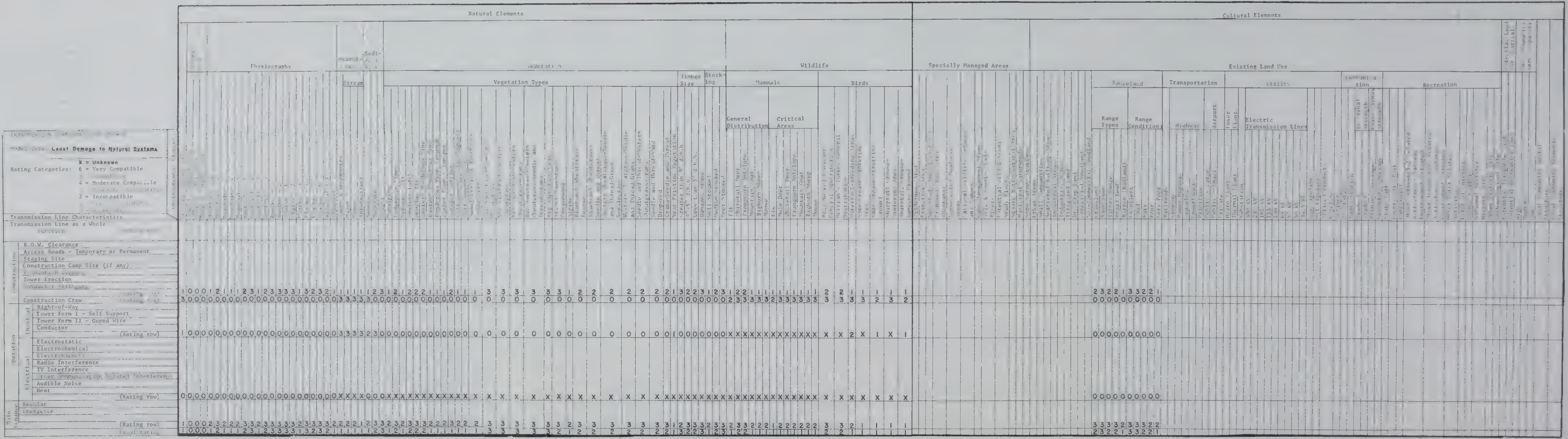
Transmission Line as a Whole
- Function (Rating row)

Construction
- R.O.W. Clearance
- Access Roads - Temporary or Permanent
- Staging Site
- Construction Camp Site (if any)
- Foundation Installation
- Tower Erection
- Conductor Stringing
- (Rating row)
- Construction Crew (Rating row)

Operation
- Physical
  - Right of Way
  - Tower Form I - Self Support
  - Tower Form II - Guyed Wire
  - Conductor
  - (Rating row)
- Electrical
  - Electrostatic
  - Electrochemical
  - Electromagnetic
  - Radio Interference
  - TV Interference
  - Other Communication Related Interference
  - Audible Noise
  - Heat
  - (Rating row)

Maintenance
- Regular
- Emergence
- (Rating row)
- Final rating

Figure I-2



Model Type: **Least Damage to Natural Systems**

Rating Categories:
X = Unknown
6 = Very Compatible
4 = Moderate Compatible
2 = Incompatible

Natural Elements: Physiography; Stream; Sedi-; Vegetation (Vegetation Types; Timber Size; Stocking); Wildlife (Mammals: General Distribution, Critical Areas; Birds)

Cultural Elements: Specially Managed Areas; Existing Land Use (Rangeland: Range Types, Range Condition; Transportation: Highway, Airport; Utility: Power Plant, Electric Transmission Lines; Communication; Recreation)

Legible column headings:
- Timber Size: Greater than 9" d.b.h.; 5"-9" d.b.h.; Less than 5" d.b.h.; Damaged Stand
- Stocking: Well Stocked; Medium Stocked; Poor Stocked
- Vegetation Types (partial): Pinyon-Juniper; Ponderosa Pine; Greasewood; Alpine; Bluebunch Wheatgrass; Fescue; Needle and Thread; Wheatgrass-Needle and Thread-Green Needlegrass; Western Wheatgrass-Needle and Thread Grama; Needle and Thread-Western Wheatgrass-Grama; Needle and Thread-Dropseed; Grama-Needle and Thread; Near Pristine Vegetation
- Mammals, General Distribution: Elk; Whitetail Deer; Pronghorn Antelope; Mountain Goat; Bighorn Sheep; Moose
- Mammals, Critical Areas: Elk; Mule Deer; Whitetail Deer; Pronghorn Antelope; Mountain Goat; Bighorn Sheep; Moose
- Birds (partial): General Distribution; Merriam's Turkey; Distribution; Sage Grouse Wintering Area; Sage Grouse Strutting Ground; Sharptail Grouse Wintering Area; Sharptail Grouse Dancing Ground
- Specially Managed Areas (partial): Wilderness Area; Primitive Area; National Wildlife Refuges; Potential Wild & Scenic Rivers; Study Rivers; Municipal Watershed; Snow Survey Station
- Existing Land Use (partial): Urban Areas; Small Communities; Scattered Built-up Area; Irrigated Land; Dry Crop Land; Commercial Woodland; Non-Commercial Woodland
- Range Types: Grassland; Sagebrush; Timber Range; Broadleaf; Barren (Badland)
- Range Condition: Excellent; Good; Fair; Poor; Very Poor
- Transportation: Railroads; Highway: Freeway; Paved Highway; Unsurfaced Road; Airport: Public - Large; Public - Small; Private
- Utility: Power Plant: Hydro Plant; Thermal Plant; Substation; Electric Transmission Lines: 500 KV; 230 KV; 161 KV; 115 KV; 100 KV; 69 KV; 57 KV; 50 KV; 34.5 KV
- Communication: TV Signal Strength; Radio Signal Strength
- Recreation: [illegible]

Transmission Line Characteristics
Transmission Line as a Whole

Construction:
- R.O.W. Clearance
- Access Roads - Temporary or Permanent
- Staging Site
- Construction Camp Site (if any)
- Foundation Excavation
- Tower Erection
- Conductor Stringing
- (Rating row): 1 0 0 0 1 2 1 1 1 2 3 1 2 3 3 3 3 1 3 2 3 2 1 1 1 1 1 1 2 3 1 2 1 2 2 2 1 1 1 2 1 1 1 3 3 3 3 3 3 1 2 2 2 2 2 2 2 1 3 2 2 3 1 2 3 1 2 2 1 1 1 1 1 1 1 1 1 1 2 2 1 1 1 1 1 … 2 3 2 2 1 3 3 2 2 1
- Construction Crew (Rating row): 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 3 3 3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 3 3 3 3 3 2 3 3 3 3 3 3 3 3 3 3 2 3 2 … 0 0 0 0 0 0 0 0 0 0

Operation, Physical:
- Right-of-Way
- Tower Form I - Self Support
- Tower Form II - Guyed Wire
- Conductor
- (Rating row): 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 3 3 3 2 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 X X X X X X X X X X X X X X X 2 X 1 X 1 … 0 0 0 0 0 0 0 0 0 0

Operation, Electrical:
- Electrostatic
- Electrochemical
- Electromagnetic
- Radio Interference
- TV Interference
- Other Communication Related Interference
- Audible Noise
- Heat
- (Rating row): 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 X X X X 0 0 0 X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X … 0 0 0 0 0 0 0 0 0 0

Maintenance:
- Regular
- Emergency
- (Rating row): 1 0 0 0 2 3 2 2 2 3 3 2 3 3 3 3 3 2 3 3 3 3 2 2 2 2 1 2 3 3 2 3 2 3 3 3 2 2 2 3 2 2 2 3 3 3 3 3 3 2 3 3 3 3 3 3 3 1 2 3 3 3 2 3 3 2 3 3 2 2 2 1 2 2 2 2 2 2 3 3 2 1 1 1 1 … 3 3 3 3 2 3 3 3 2 2

Final rating: 1 0 0 0 1 2 1 1 1 2 3 1 2 3 3 3 3 1 3 2 3 2 1 1 1 1 1 1 2 3 1 2 1 2 2 2 1 1 1 1 1 1 1 3 3 3 3 3 2 1 2 2 2 2 2 2 2 1 3 2 2 3 1 2 3 1 2 2 1 1 1 1 1 1 1 1 1 1 2 2 1 1 1 1 1 … 2 3 2 2 1 3 3 2 2 1

Figure I-3

son can be materialized by combining (or overlaping) various concerns with different ratings. Only a computer can conduct such a massive and lengthy combination process efficiently.

F. Impact Evaluation

After the final corridor is selected, the impact of this route on the cultural and natural environment is evaluated.

A public involvement program will be developed separately to bring about interaction with the public periodically.

CHAPTER TWO Need For The Proposed Facility

The need for two 500 KV lines between Colstrip and Hot Springs depends upon the existence of both an energy source at Colstrip (Units 3 and 4) and an energy need at Hot Springs or some location for which Hot Springs is a logical intermediate delivery point. The dependence on an energy source at Colstrip means that the transmission lines cannot be viewed separately from Units 3 and 4.

Consideration of the need for Units 3 and 4 is treated in Chapter Four of Volume 2. It is pointed out there that need cannot be evaluated in a unanimously agreed upon, precise manner; need means different things to different people. The only thing that can be viewed with unanimity is the record of past consumption. As soon as the relationship between need (past, present or future) and consumption (past, present or future) is discussed, unanimity is lost.

When we leave the historical record of consumption and begin to project future consumption, complete agreement is again lost. The same data can yield different projections depending on what one considers to be the relevant time span to include and what assumptions are made regarding underlying relationships that the data embodies. In addition to these two areas of interpretation of the data, there is also the question of how much additional information, not included in the data itself, should be utilized. Furthermore, there is the question of whether or not background conditions, such as a slowdown in population growth rates or changes in economic growth projections should be included.

In Chapter Four, Volume 2 a rough comparison of projected consumption and projected generating capability was made for the Northwest Power Pool and the applicant companies.

In Chapter Six, Volume 2 load site generation was investigated as an alternative to mine site (Colstrip) generation. Two somewhat arbitrarily chosen sites (Hot Springs and Spokane) closer to the load centers were used to compare the costs of building generation at Colstrip and transmitting the electricity (as proposed by the applicants) versus shipping the coal by unit train to those sites and generating there. These comparisons show the arbitrary sites to be economically feasible, and thus real alternatives to building generating units at Colstrip and transmission lines to Hot Springs do appear to exist.

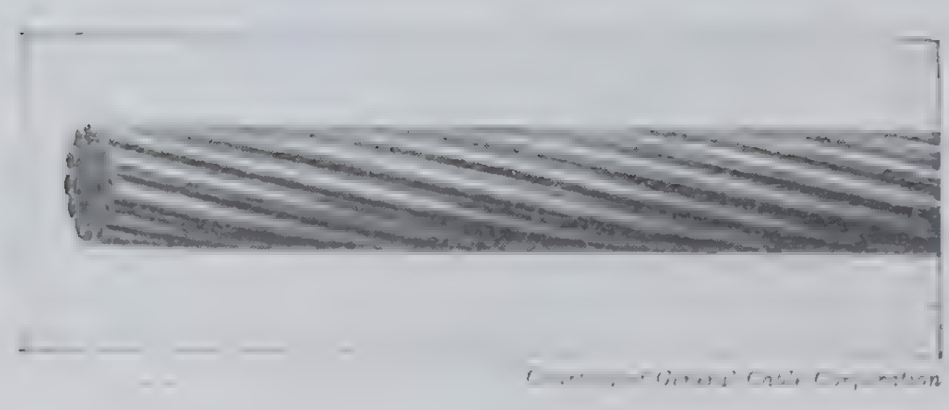
CHAPTER THREE Alternative Transmission Technology

3.1. General Discussion

Metals are good carriers of electrical power, with copper considered to be the best commonly available metal, followed by aluminum. A conductor consists of more than one wire woven together (see Figure 3-1, copper conductor). Since aluminum wire, which is lighter in weight than copper and cheaper in priced, has less mechanical strength, it is usually reinforced with steel, making a conductor known as ACSR (Aluminum Conductor Steel Reinforced--Figure 3-2). This type is the standard transmission line conductor.

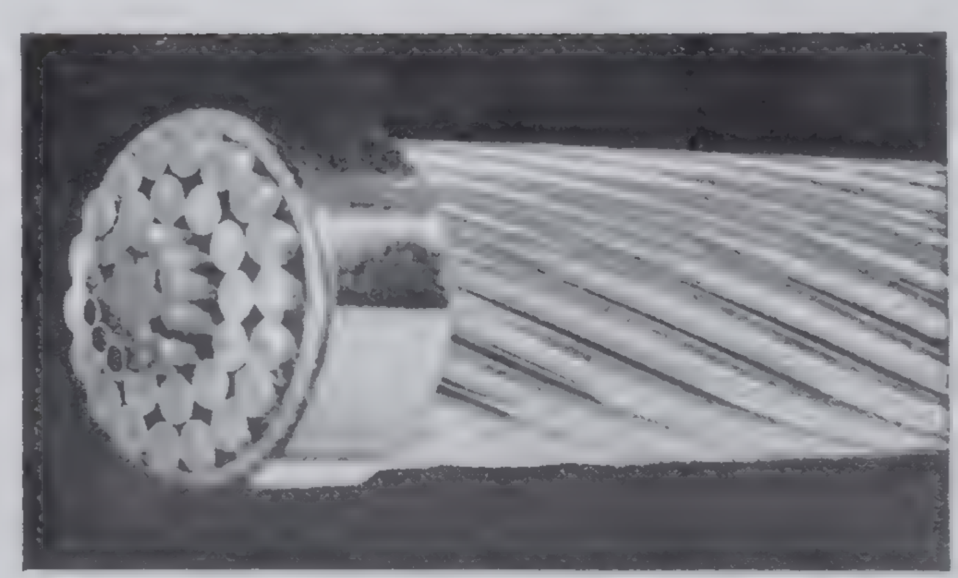
The flow of current in a conductor is measured much like the flow of water in a pipe, except that current is measured in units called amperes. The potential difference in the conductor, similar to a difference in pressure between two points in a water pipe, is measured in volts. The total amount of energy is measured in watts, similar to water being measured in gallons per minute considering the same elevation. The prefixes "kilo", "mega", and "giga" are used to denote multiplication by one thousand, one million, and one billion times, respectively.

Water flowing through a pipe experiences some losses in volume and velocity through such things as resistance of the pipe walls, head loss, and water leakage at joints and ends. Current flowing in a conductor also experiences losses--resistance loss (R) in both alternating and direct current (A.C. and D.C.), inductive



Courtesy of General Cable Corporation

Copper Conductor
Figure 3-1



Courtesy of Aluminum Company of America

ASCR
(Aluminum Conductor Steel Reinforced)
Figure 3-2

loss (jX_L) in A.C. current only, and capacitive loss (jX_C) in A.C. current only. Useful current, then, is always less than the total current in an electrical device, and this relationship (between useful current and total current) is known as the power factor ($\cos\phi$) (see Section 3.2.2.).

The interrelation of these units is expressed as follows:

1) $$A(\text{mpere}) = \frac{V(\text{oltage})}{(R+jX_L+jX_C)}$$

Or, assuming jX_L and jX_C to be very small, $A=\frac{V}{R}$

$V \approx AR$

2) $$W(\text{att}) = V \times A - \text{losses}$$
or
$$W = V \times A \times \cos\phi$$

3) $$\text{Total Energy} = V \times A$$

When a large amount of energy needs to be transmitted, then, (as expressed in equation 3), values of V and A must be high, but any conductor has a maximum value for A, due to the characteristics of conductor resistance, which cannot be exceeded or eliminated, just as one cannot eliminate friction loss in a water pipe. Generally, A can be increased with the size and number of conductors, but this reaches a practical limit. Since the maximum value of A is fixed by the selection of the conductor, the most effective and practical variable is voltage. Combining equations 1) and 3) gives:

4) $$\text{Total Energy} = V \times \frac{V}{(R+jX_L+jX_C)} = \frac{V^2}{(R+jX_L+jX_C)}$$

If it is assumed that $R+jX+jX = 1$, then

5) $$\text{T.E.} = V^2$$

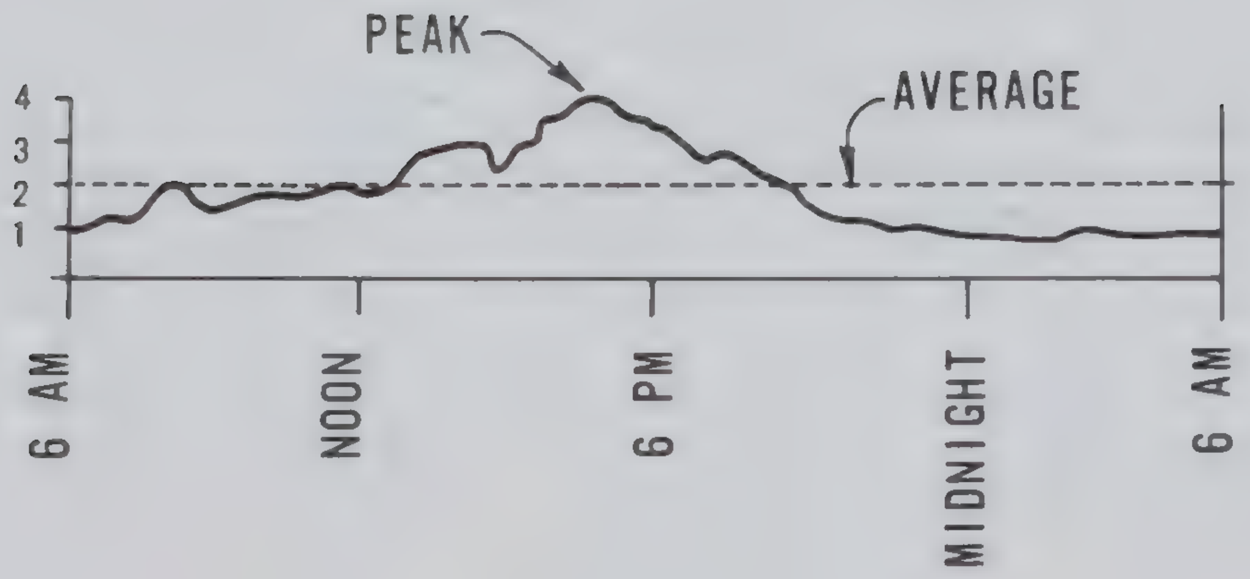
Equation 5) is illustrated in Table 3-1, which shows the major advantage of increasing the voltage level.

Table 3-1

Voltage	(Total Energy)
1	1
10	100
100	10,000 (10 KVA)
1000 (1 KV)	1,000,000 (1 MVA)
100,000 (100 KV)	10,000,000,000 (10 GVA)
500,000 (500 KV)	250,000,000,000 (250 GVA)

Some problems which arise when the voltage level is above 100,000 volts are discussed in Section 4.3.1.

Unlike water, electric energy cannot be stored in its "pure" state. If it is necessary to store electric energy, it must be converted into the potential energy of stored water, the chemical energy of batteries, or such energy products as hydrogen gas. It must be available as demand dictates, and demand is constantly changing. Figure 3-3 illustrates demand for one day in one town, taken as an example.



ELECTRIC ENERGY DEMAND

FIGURE 3-3

Though total demand is only one unit at 6:00 A.M., at 6:00 P.M. it may be three to four times higher. Considering unexpected outages at the plant, generation capacity for each city should be adequate to meet the peak demand. However, if each city kept adequate generation 24 hours a day to supply its short peak demand, the cost of the system would be prohibitive. For this reason interconnection of generating plants and load centers took place, making a "grid" system. The major technical difficulty is maintaining the stability of the system (see Section 3.3. and Appendix I1). No city or region can remain isolated in the grid system; each shares the demand changes of the neighboring city or region. Section 3.3. contains a more detailed discussion of the grid system which affects Montana.

It should be noted that definitions of many terms used throughout this chapter and Chapter Four are located in the glossary at the end of this volume.

3.1.1. Line Reliability

A major problem with transmission line systems is outages, both forced (unexpected faults) and scheduled (for maintenance and other purposes). During a line outage, service to customers may be affected if that service is supplied by only one line. The ability of a transmission system to provide continuous service despite outages is called line reliability.

When a major load center is served by only one transmission line, line reliability is minimum; if that line should have an outage, the service area would not receive power until the outage is over. If another line with adequate capacity were added to that system, one line could supply the required load when an outage occurred on the other. It is unlikely that both lines would suffer an outage at the same time, especially if the two lines follow different routes. Adding a second line to a system, then, depending on the location of that line, will increase the line reliability. Adding a third line to the system would again increase line reliability, but the increment of line reliability increase varies inversely with the number of lines added. Therefore, two lines are usually considered sufficient for line reliability, when each line individually can carry the total required load.

Natural causes of line outages include lightning and other phenomena associated with storms, fire, frost and ice, earthquakes, and downed trees. Technical causes include line material failure, improper relaying, overloading, accidental tripping, and many other system malfunctions. Man can accidentally or purposely damage a line or other equipment and cause system outages.

Table 3-2 contains a summarized analysis of forced transmission line outages in the BPA system. In addition to the outages in that table, there were scheduled outages for maintenance of unknown duration. Table 3-3 contains outage information for 230 KV lines in Montana (MPC 1974).

3.2. Alternative Systems of Transmission

3.2.1. Direct Current

3.2.1.1. History

The discovery of electricity was actually of direct current (D.C.) electricity, and the commercial applications of that discovery also used direct current. In 1882 Thomas A. Edison built the first electrical central station, which transmitted 110 V direct current through underground tubular mains over a radius of one mile. The first use of electricity in communication was in D.C. telegraphy. However, as the demand for electricity increased, it was necessary to raise the voltage level above 110 V, and problems of D.C. generation at higher voltages became more complex and unavoidable.

3.2.1.2. D.C. Generation

In the early 19th century D.C. generators were used for D.C. power. D.C. generators have commutators (Figure 3-4) which are copper bars working as outlets for the current produced by the machine. To avoid excessive sparking, voltage per bar should not exceed 24 volts. This limitation forces the use of many bars for high-voltage D.C. generators, thus increasing the diameter of the generator. A large diameter machine cannot be designed to operate at high speeds due to the effects of centrifugal force on commutators and windings. Low-speed machines are heavier, more expensive, and less efficient than high-speed machines.

TABLE 3-2

FORCED OUTAGES ON 500, 230, and 115 KV BPA TRANSMISSION SYSTEMS (OREGON, WASHINGTON, AND WEST OF CONTINENTAL DIVIDE)

Voltage	Total Number of Lines	Total Outages	Total Time Lost in Outages	Number of Outages Due To					
				Lightning	Fire	Terminal Eq. Failure	Overload	Accidental Tripping	Other
500 KV	28	90	192 hrs	10	-	11	-	13	56
230 KV	90	139	442 hrs	47	4	9	3	20	56
115 KV	160	150	1,583 hrs	43	2	4	13	5	83

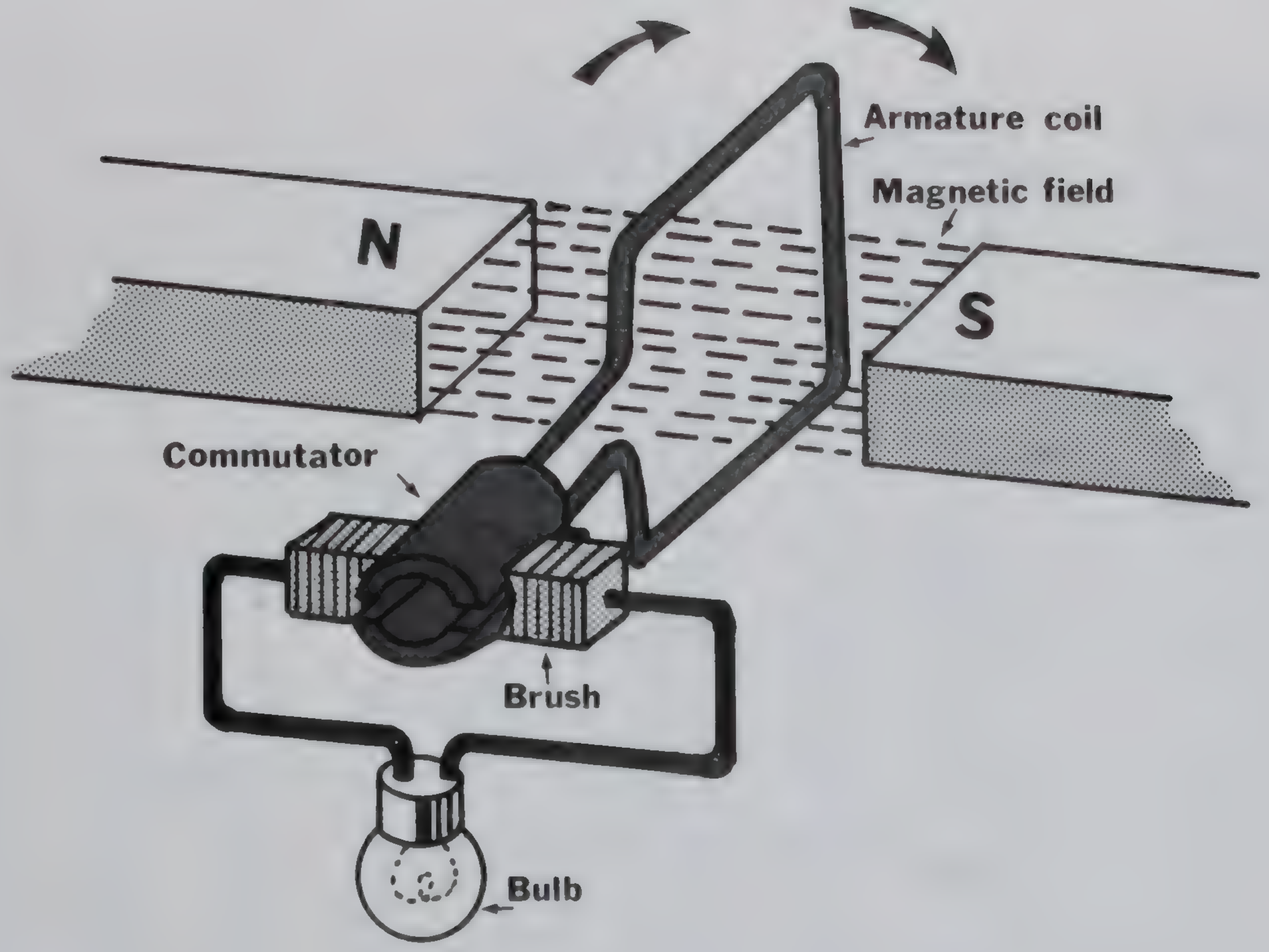
(BPA 1974)

TABLE 3-3

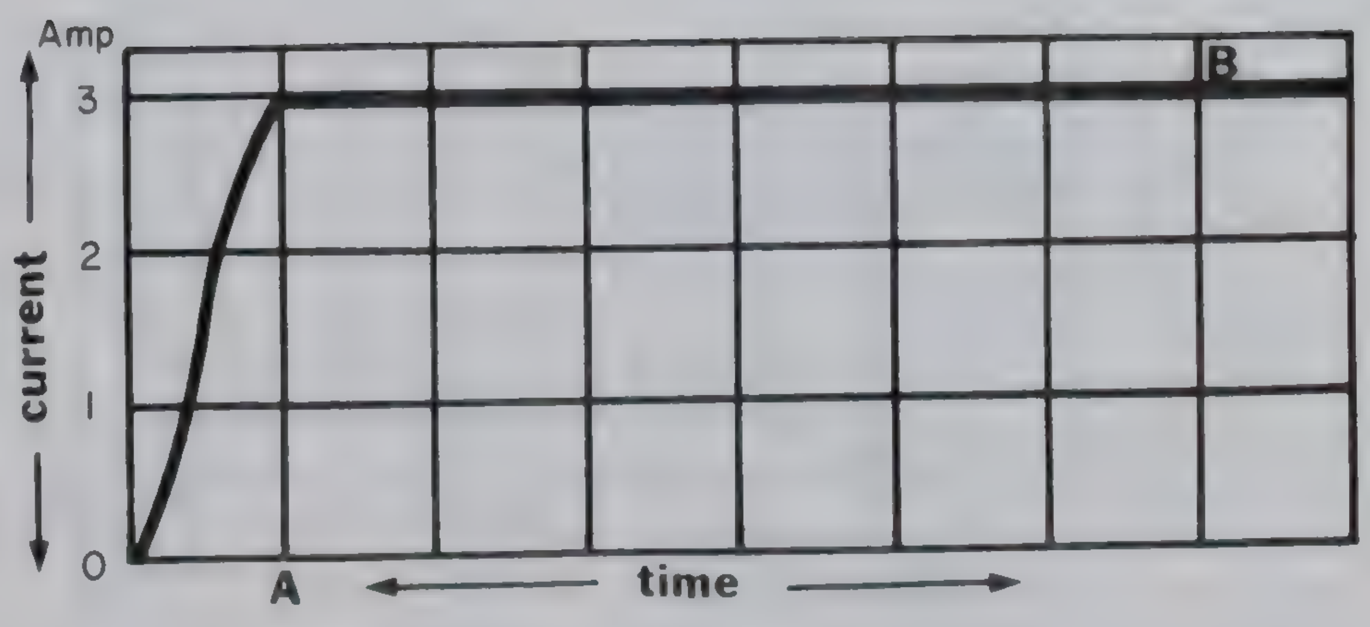
OUTAGES ON 230 KV LINES IN MONTANA

Year	Forced Outages	Total Down Time	Main Reasons For Forced Outages	Scheduled Outages	Total Down Time
1969	9	241:31 hrs	Plane crash; tree in line	51	336:26 hrs
1970	17	25:57 hrs	Insulator failure; lightning	76	638:34 hrs
1971	4	11.42 hrs	Broken static wire	91	745:38 hrs
1972	19	36:02 hrs	Ice, wind, lightning	29	129:17 hrs
1973	5	28:32 hrs	Lightning; shooting of insulators; dropping of phase wire	8	23:26 hrs

(MPC 1974)



SIMPLIFIED D.C. GENERATOR



DIRECT CURRENT WAVE

FIGURE 3-4

(Wellman 1959)

The design of the circuit breakers used in the opening and closing of a high-voltage D.C. system is still at the research stage. Because very little advanced research in D.C. generation and related problems has been done, this type of generation is no longer used in large power plants.

3.2.1.3. High Voltage D.C. Transmission

At the present time, high voltage (H.V.) D.C. transmission requires converters which consist of mercury arc rectifiers (Figure 3-5) at the generating substation which convert current from A.C. generators to direct current to be fed into the D.C. transmission system, and inverters, which convert D.C. back to A.C., at the receiving station. Using a recently developed technique, mercury arc rectifiers can be replaced by solid state devices using thyristors.

There are three methods of H.V.D.C. transmission:

1) Monopolar (see Figure 3-6)

This system uses one conductor, usually of negative polarity, and can use either ground or sea as a return conductor. Only one rectifier-inverter set is necessary.

2) Bipolar (see Figure 3-7)

This system consists of two conductors, one for positive and one for negative polarity. For example, the rated voltage for a 100 KV system is expressed as ±100 KV (read plus and minus 100 KV). Two rectifier-inverter sets are required. Neutral points (junctions between converters) are grounded at one or both ends of the transmission line. When both ends are grounded, the system is like two monopolar systems connected in parallel; in the event of a fault in any one converter, another converter with ground return (where the ground will act as conductor) can carry from 50% to 66% of the total power of the system.

3) Homopolar (see Figure 3-8)

This system consists of two or more conductors of the same polarity and ground return. In the event of a fault on any conductor, the affected converter can be used by the other conductor(s), and with some overloading the system can carry the entire power load.

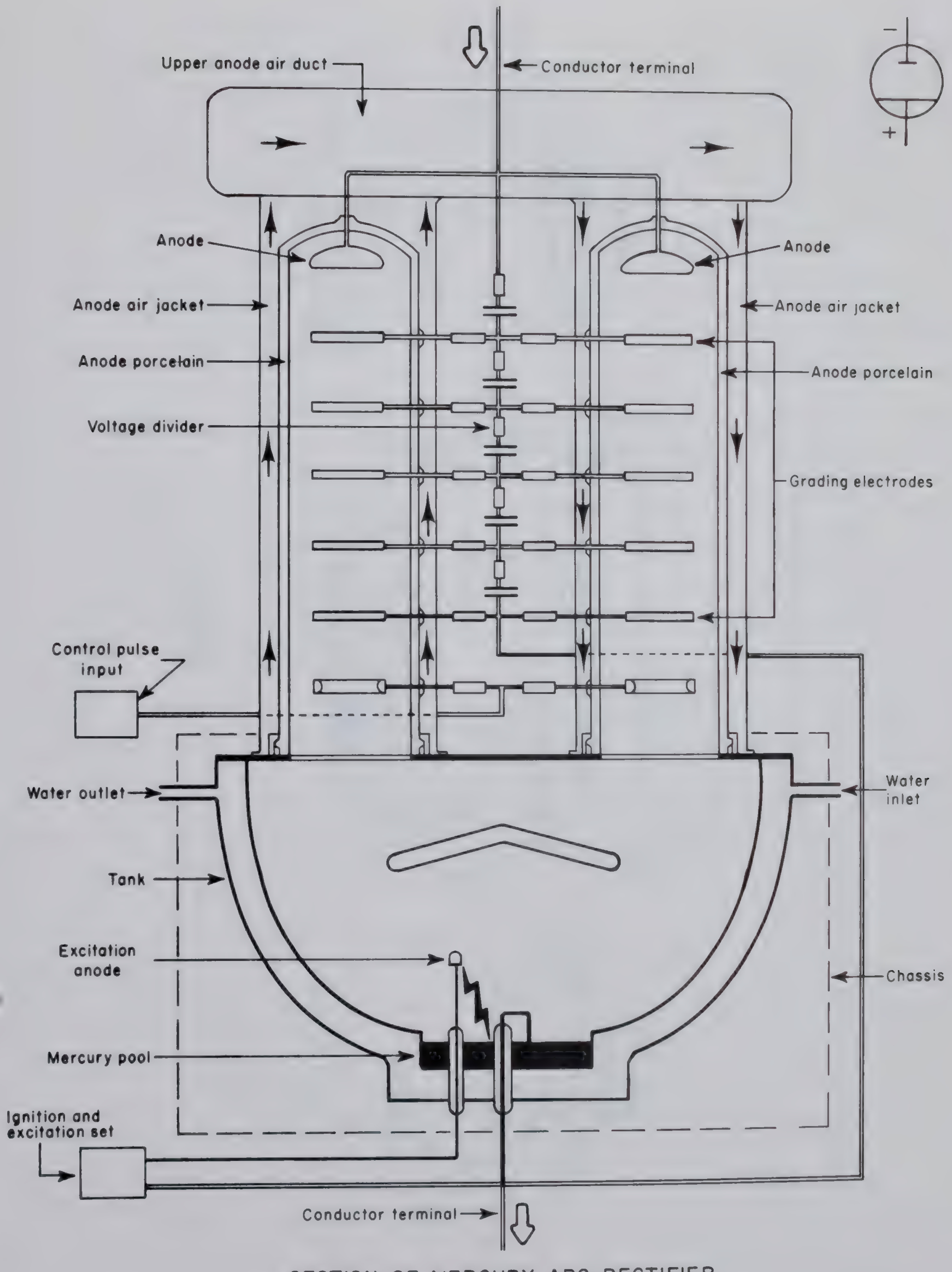
Use of converters in any D.C. transmission system characteristically produces harmonics (multiple frequencies of 60 cycles) which may cause interference with audio-frequency telephone lines. To prevent this, filters are required for both inverters and rectifiers, which, of course, increase the cost of conversion.

In summary, these are the advantages of H.V.D.C.:

1) Line construction is simpler. Ground return can be used.

2) Because only one or two conductors are needed, line cost is low.

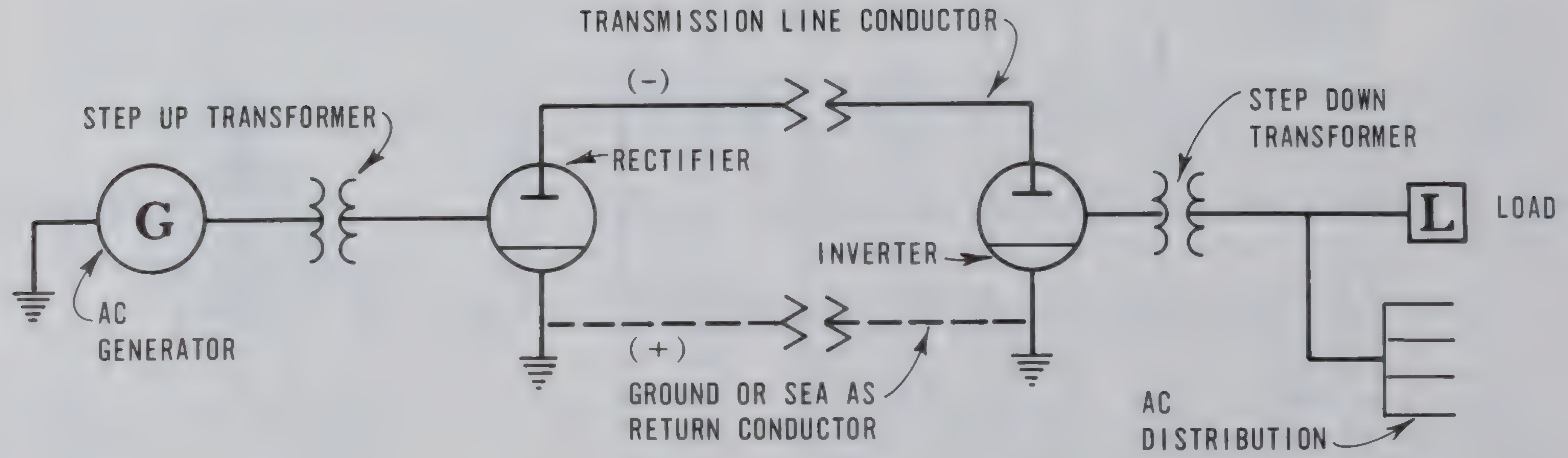
3) Each conductor can be operated as an independent circuit.



SECTION OF MERCURY ARC RECTIFIER

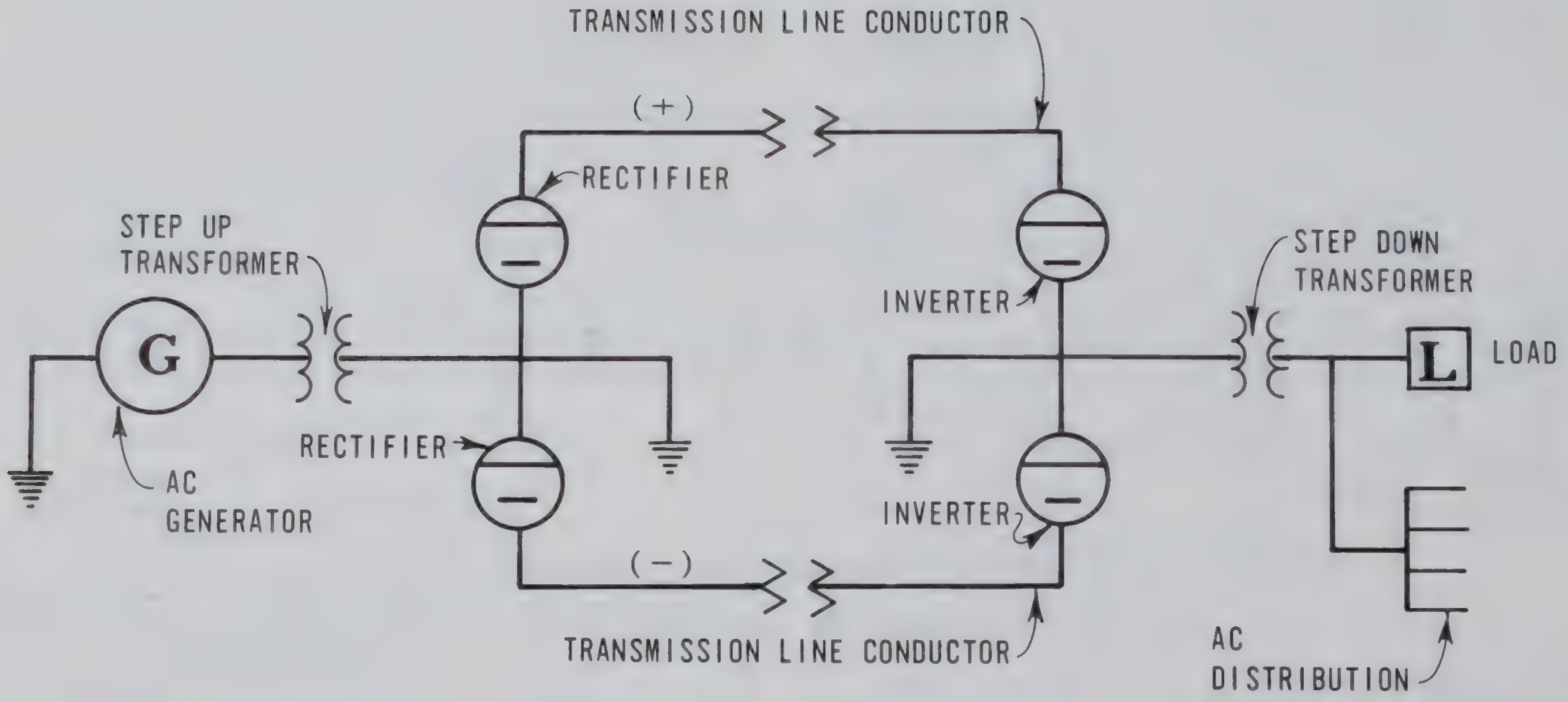
FIGURE 3–5

(U.S.D.I. 1970)



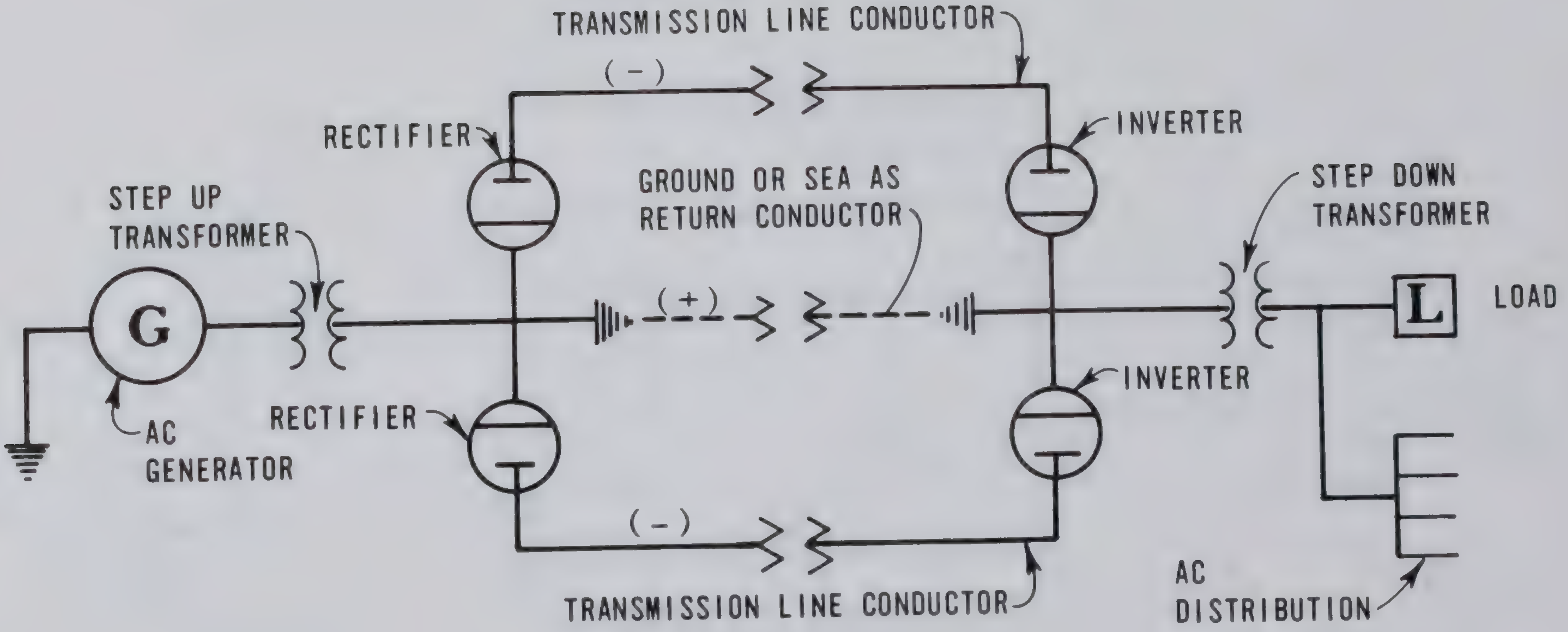
MONOPOLAR

FIGURE 3-6



BIPOLAR

FIGURE 3-7



HOMOPOLAR

FIGURE 3-8

4) An H.V.D.C. system has only resistive losses (see Section 3.2.2.). There is a smaller amount of line loss, less corona loss (for discussion of corona see Section 4.2.1.3.), and less radio and T.V. interference, especially in foul weather.

5) The length of the line is not limited by stability. Synchronous operation is not required (see Appendix I1).

6) D.C. has less overall cost than A.C. for long distance transmission without intermediate tapping. (See Figure 3-9 for comparison of A.C. and D.C.).

The disadvantages of H.V.D.C. are:

1) Converters are expensive.

2) Because the converters generate harmonics, filters are needed, causing further expense and technical problems.

3) Adequate H.V.D.C. circuit breakers have not yet been developed.

4) Tapping of line is expensive.

5) Ground return may result in ground currents straying into underground metallic systems, such as pipe lines, and affecting the electrical grounding of other systems.

Figure 3-10, which shows existing D.C. transmission lines using converters, gives some idea of the extent of D.C. transmission.

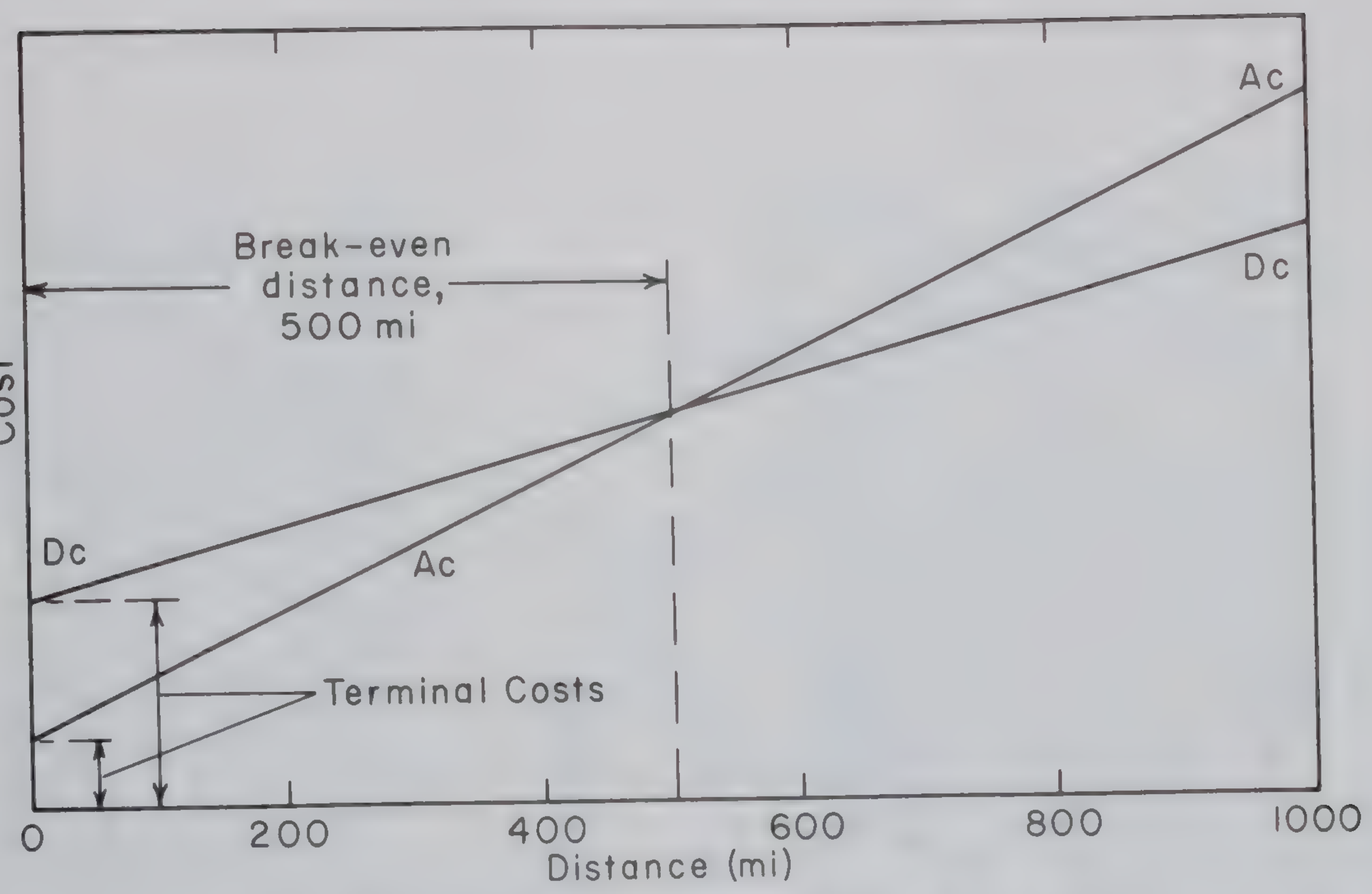
3.2.1.4. Future of D.C. Transmission

New methods of D.C. generation, such as thermoelectric, magneto-hydrodynamic, and fuel cells (see Volume 2, Section 5.2.) inherently generate direct current. When these are developed, D.C. transmission will be more attractive to utilities. If superconductivity (see Appendix I3) in cables becomes less expensive and more technologically practical, utilities may incorporate underground D.C. transmission at low voltage and high amperage into their transmission systems. Further improvements in technology and reduction of cost of conversion for terminals and taps would also enhance the future of D.C. transmission.

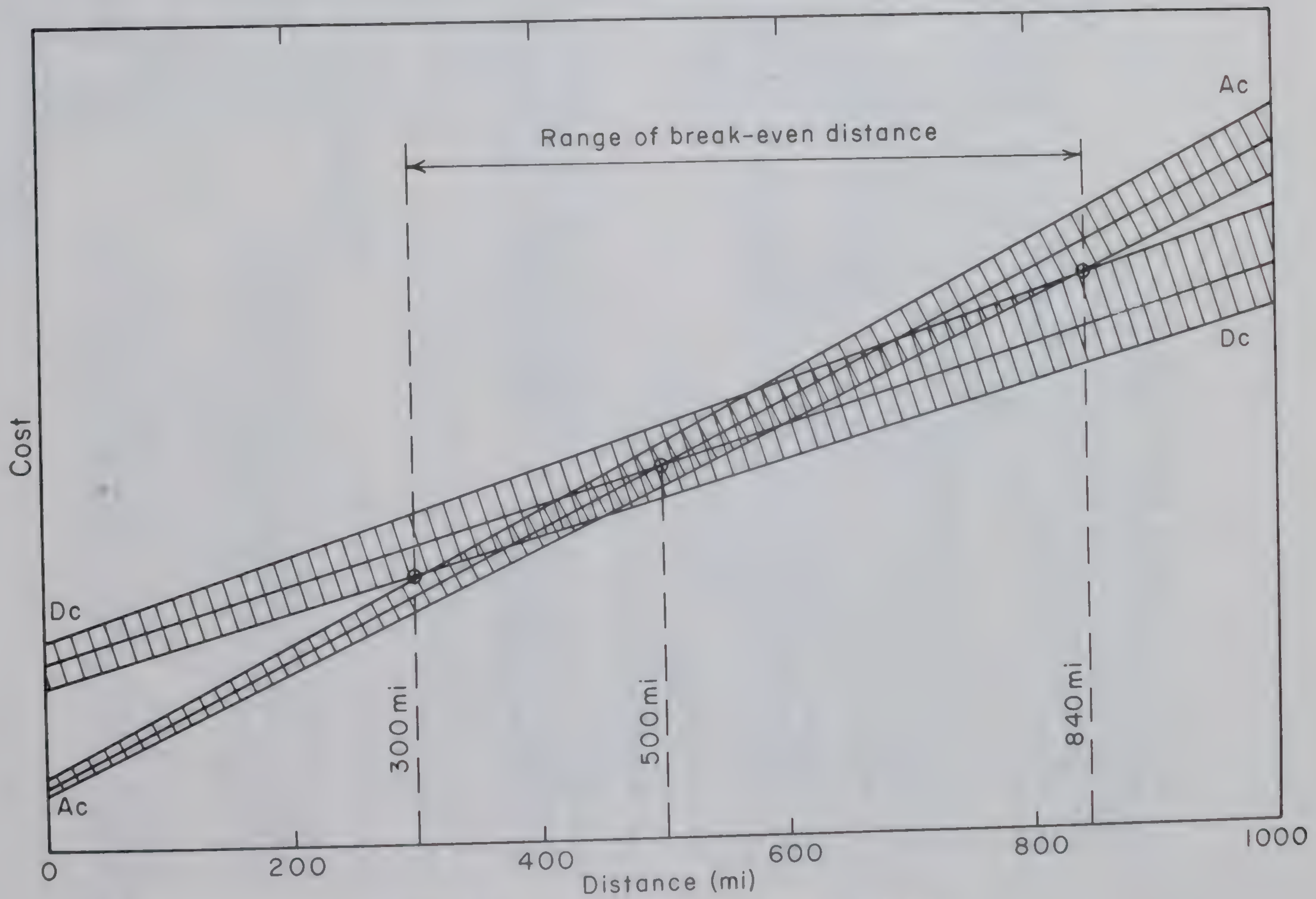
3.2.2. Alternating Current

3.2.2.1. History

In the late 1870's and early 1880's, the development of the transformer, polyphase circuit and induction motor led to the discovery of the alternating current (A.C.) power system. A.C. generators (Figure 3-11) and alternators (Figure 3-12) became practical alternatives for power generation in the early 1900's. The A.C. system is based on the principle of induction: a current passing through one conductor will induce current in an adjacent conductor. A.C. transformers and induction motors have very low power losses. Another main attraction of the A.C. system is that power can be generated at low voltage, stepped up by transformers for high voltage low-loss transmission, and stepped down again at the receiving station for distribution.



COMPARATIVE COSTS OF AC AND DC
OVERHEAD LINES VERSUS DISTANCE

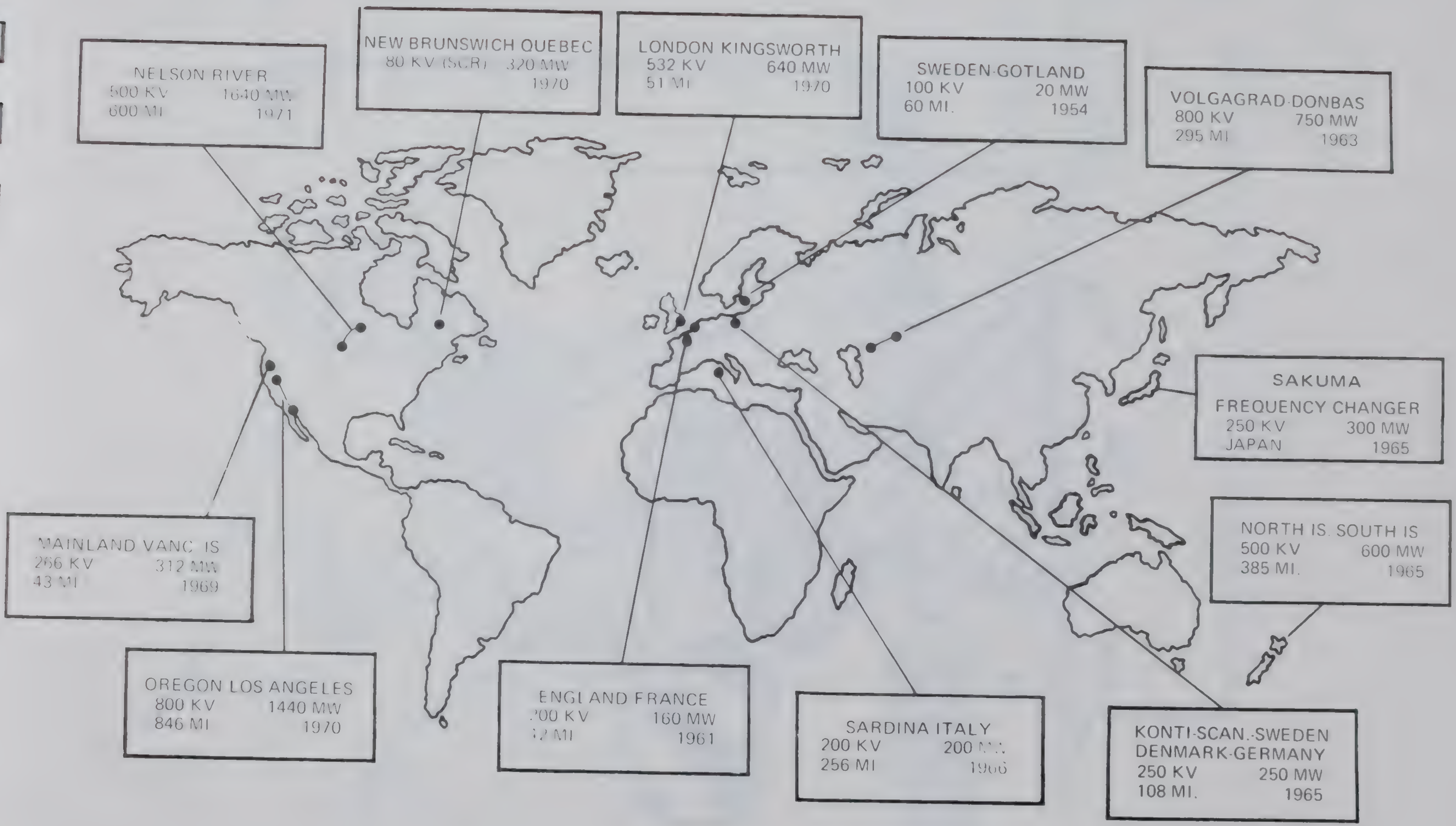


EFFECT OF VARIATION OF COSTS
ON BREAK-EVEN DISTANCE

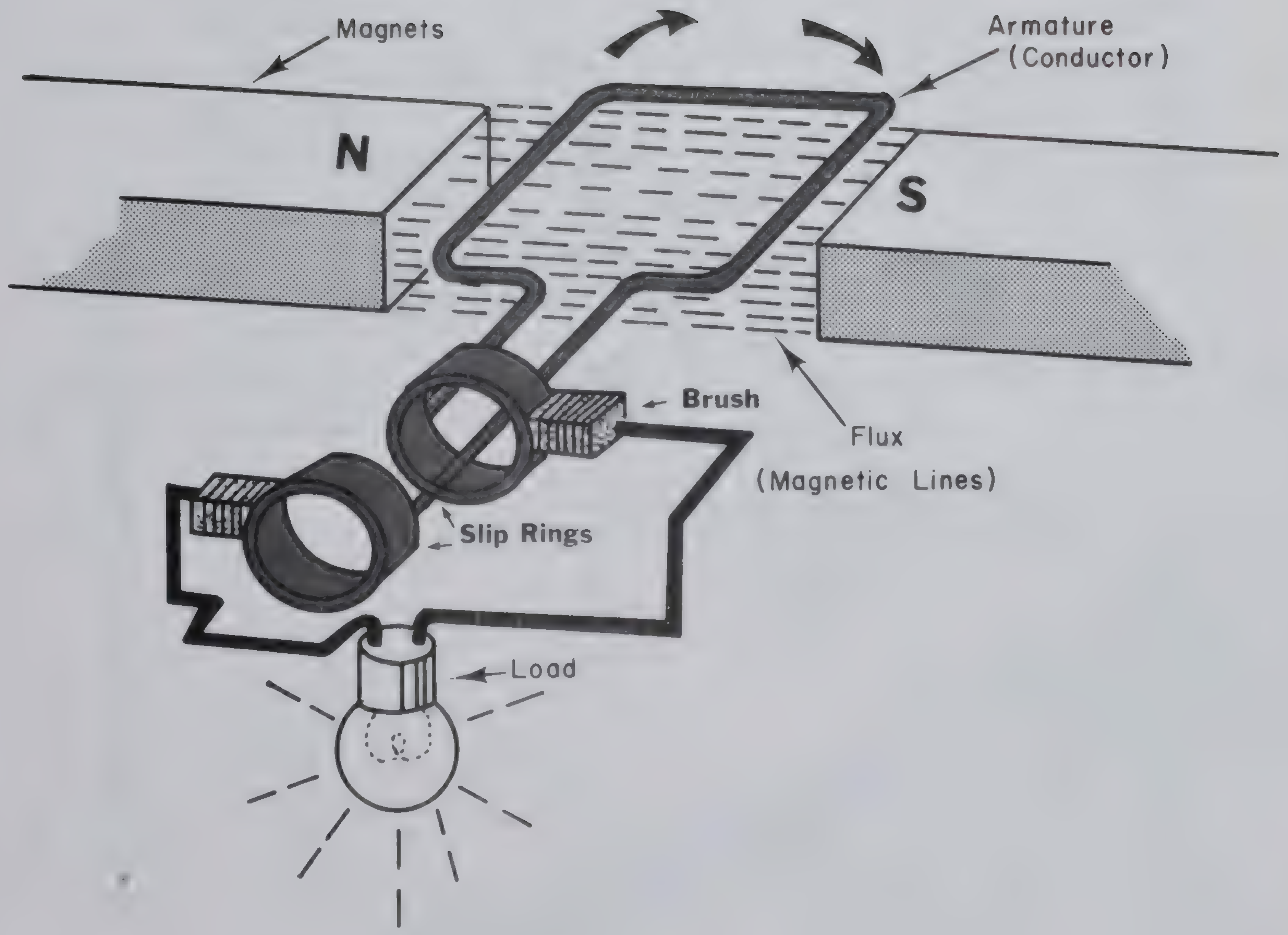
FIGURE 3-9 (Kimbark, 1973)

HIGH VOLTAGE DC POWER TRANSMISSION

— THROUGHOUT THE WORLD —



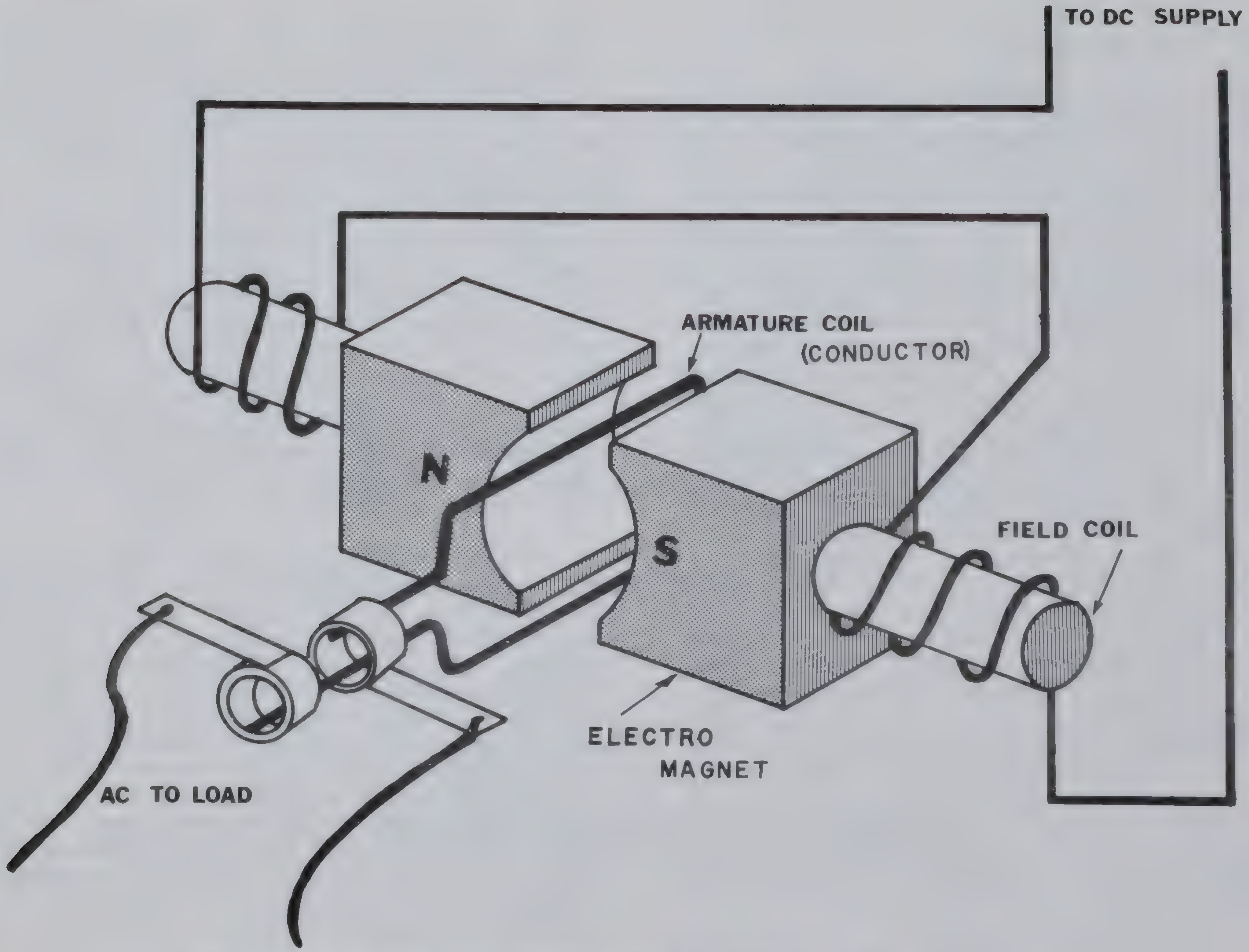
DC Converter Facilities Throughout the World.



SIMPLIFIED A.C. GENERATOR

FIGURE 3-11

(Wellman 1959)



SIMPLIFIED REVOLVING-ARMATURE ALTERNATOR

FIGURE 3-12

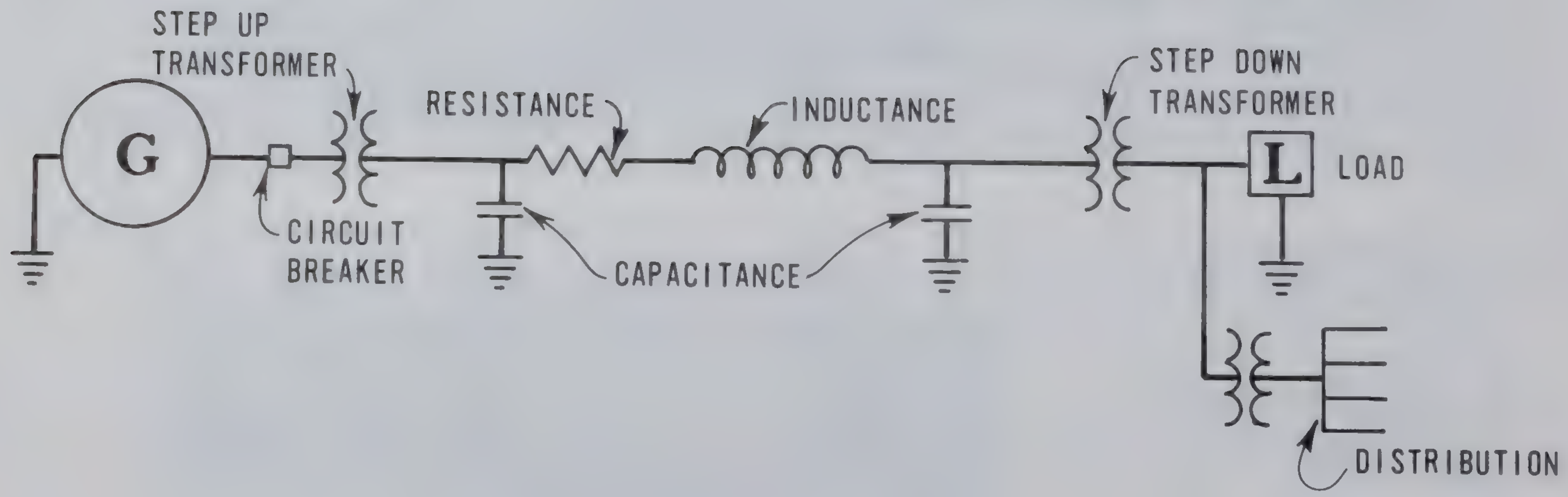
(Wellman 1959)

3.2.2.2. A.C. Transmission

Unlike D.C. transmission, which can be accomplished by any one of three methods, A.C. transmission has one primary method (Figure 3-13) which includes a generator, followed by the transformer (Figure 3-14) and transmission line. (For discussion of A.C. circuit breakers and relays, see Appendix I2.) The A.C. system has characteristics that D.C. does not. The A.C. wave form (Figure 3-15) is one way to visualize the changing A.C. voltage and current. Continuous changes of magnitude and direction in voltage and current also cause the electromagnetic (pattern of induction) field to constantly change. This induces current in the opposite direction in the conductor, which is called self induction; when current is induced in an adjacent conductor it is called mutual induction. Then, current will not be in phase with voltage but instead will be "lagging" behind the voltage (Figure 3-16). The same changing electromagnetic field also induces voltage on non-conducting materials. This is called the capacitive effect. In this case the current is leading or is ahead of the voltage (Figure 3-16). To minimize inductive effect, capacitors are connected in series, and to minimize capacitive effect, reactors (or induction coils) are connected in parallel. However, synchronous condensors, which can be made to work either way, are most commonly used. These corrections to the A.C. system minimize losses and are referred to as compensation. Compensation also improves system stability.

The leading and lagging effect shown in Figure 3-16 is also known as angular phase shifting, and is expressed in electrical degree-ϕ° ($\pm/^{\circ}$). Power factor has a relation with phase shifting, expressed as $PF = \text{cosine}\ \phi$. Phase shifting creates additional generation problems. When two power generators are connected in parallel, and phase shifting occurs, they are out of synchronization. When this happens, internal flow of currents and related problems occur. One problem is a drop in voltage and current at the receiving end of the transmission line which, if excessive, can damage consumers electrical equipment. Under normal conditions no greater variation in voltage level than ±5% is allowable. This problem becomes critical when two transmission lines or two generating plants need to be interconnected, but can be overcome with proper design. A system with minimal phase shifting and consistent electrical characteristics is a stable system. System stability is essential and is a major design concern.

The discussion above refers only to overhead A.C. transmission, for which all major technical problems that have arisen have been solved up to the 765 KV voltage level. Underground A.C. transmission, on the other hand, has many unsolved technical limitations (discussed in Section 3.2.3.) as well as economic limitations. Since utility companies place great importance on economic considerations, they are presently convinced of the desirability of overhead A.C. transmission, which is cheaper in most cases than D.C. overhead transmission and all underground transmission (see Figure 3-9). The major advantage of overhead A.C. transmission is that the overall cost of electricity is low.



SIMPLE REPRESENTATION OF A.C. TRANSMISSION

FIGURE 3-13

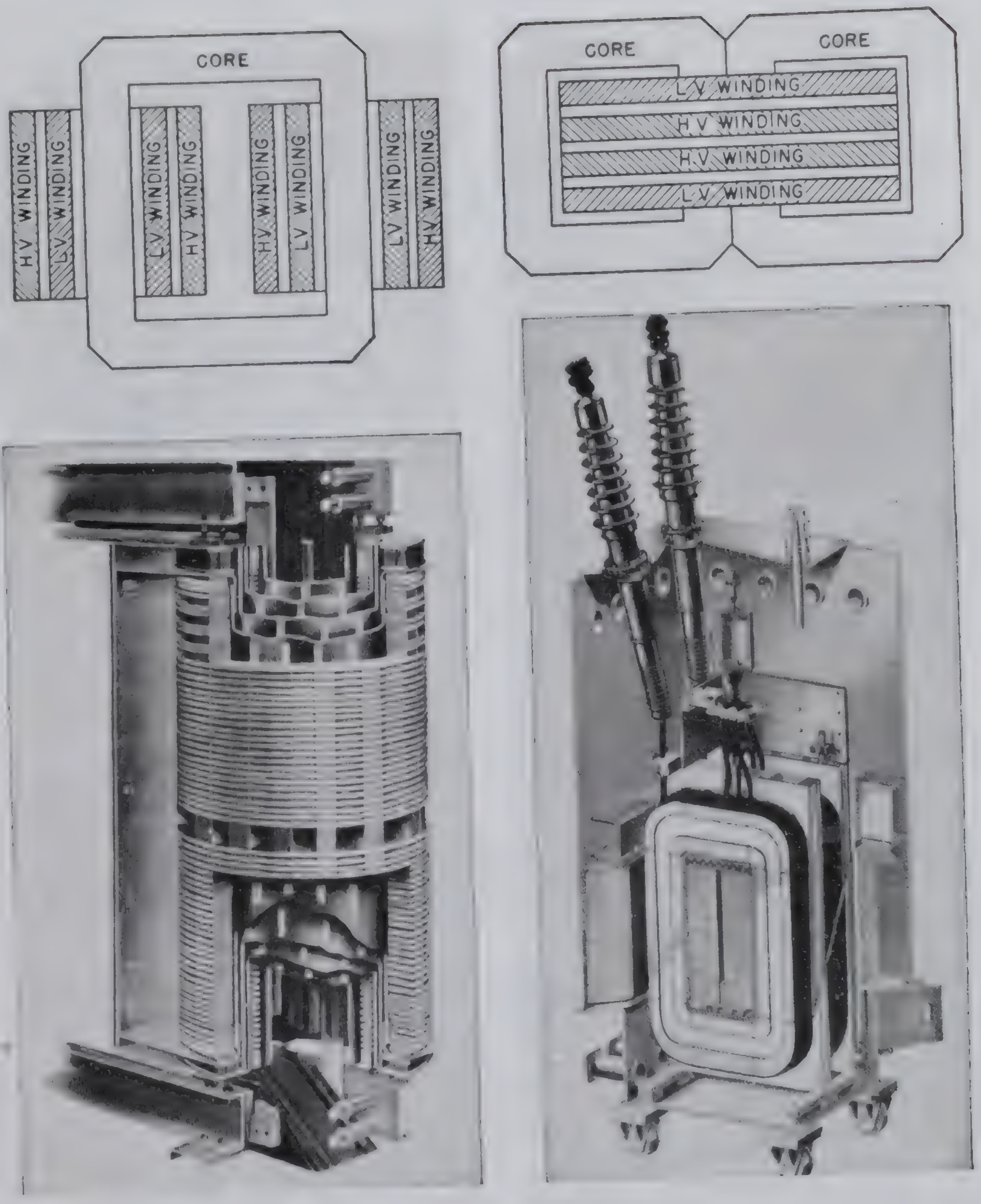
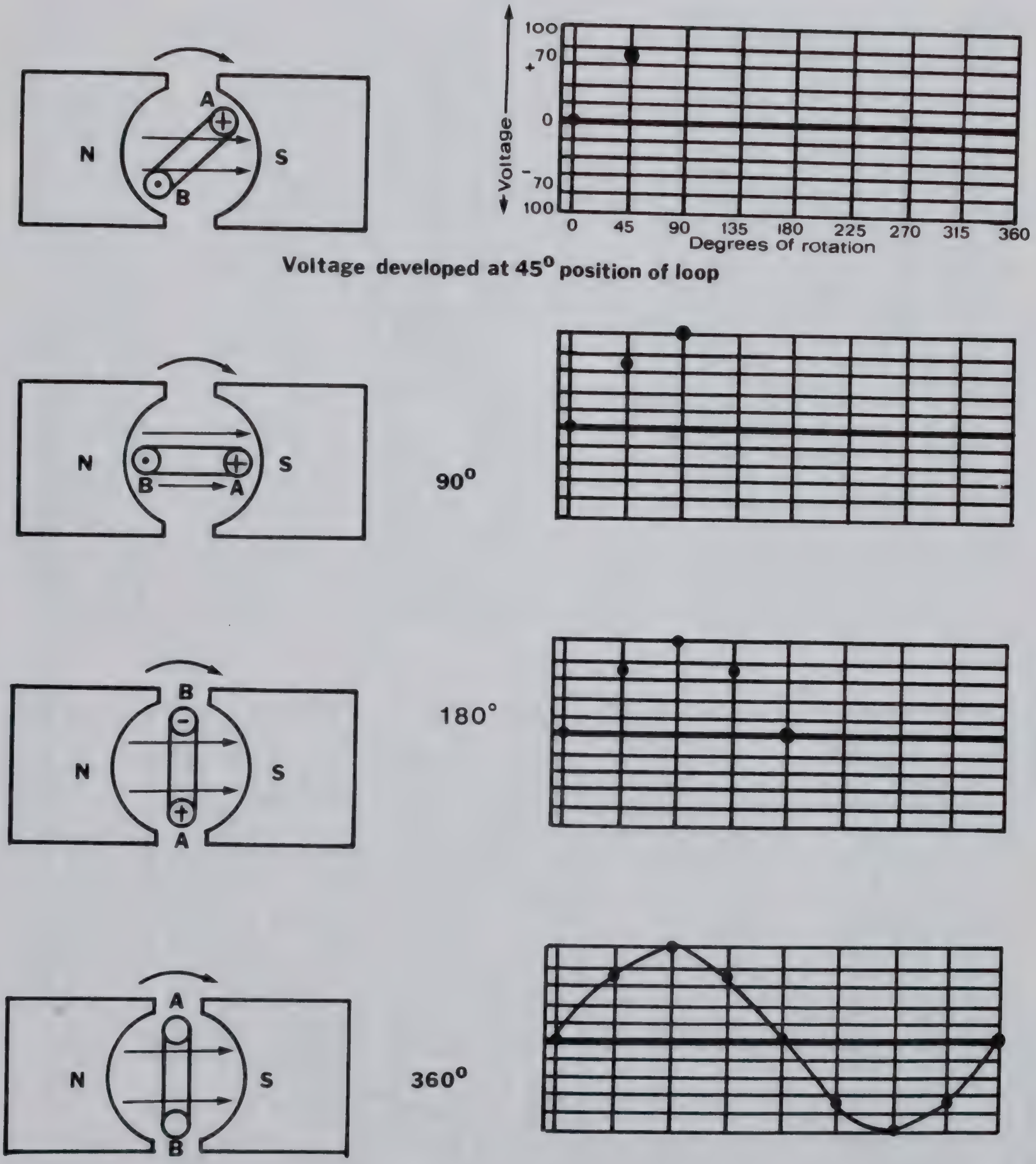


Figure 3-14: Transformers

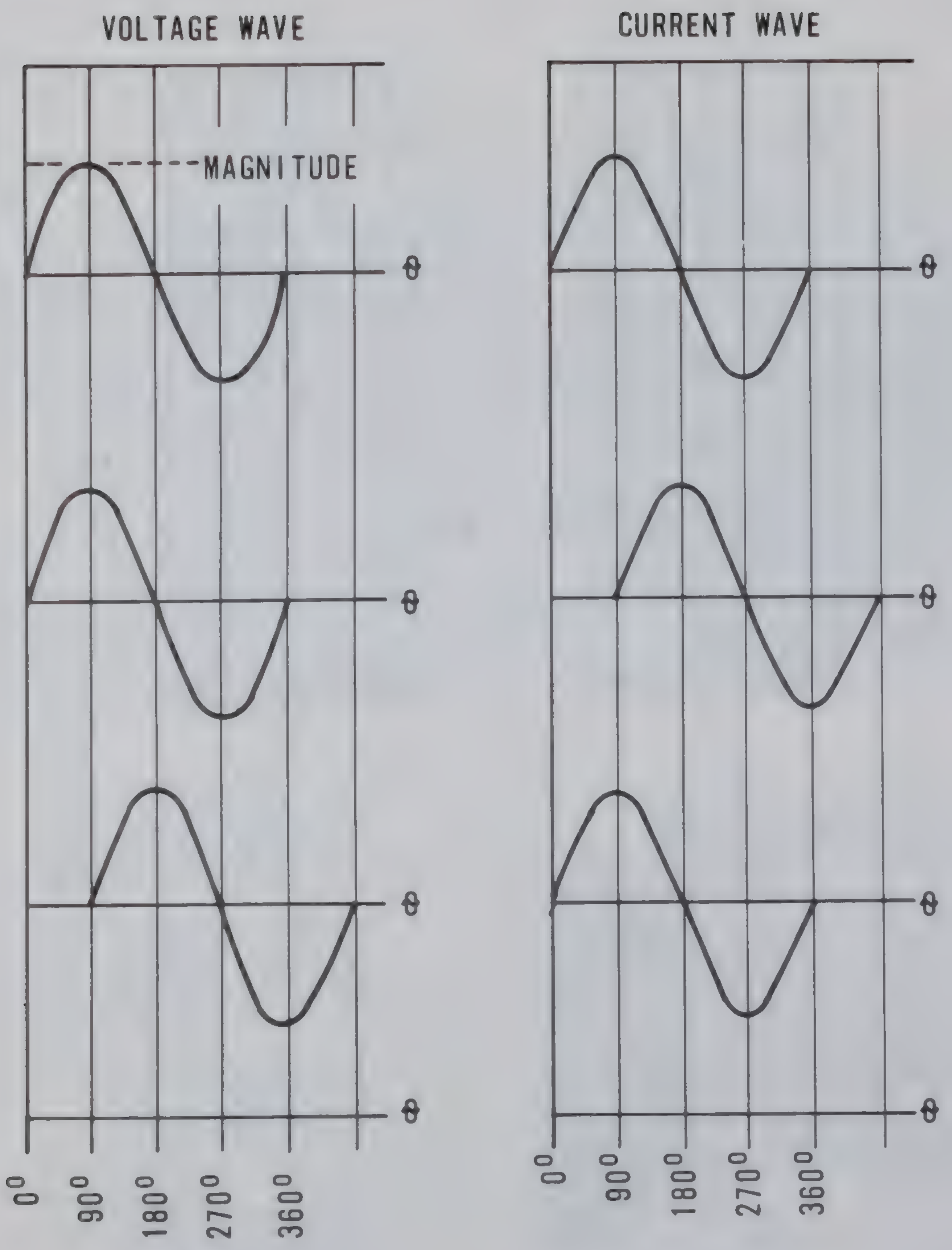
Single Phase Core Type

Single Phase Core Type



A-C WAVE SHAPE OF VOLTAGE & CURRENT

FIGURE 3-15 (Wellman 1959)



Resistive Circuit

current is in same phase
with voltage
$\theta = 0^0$
P.F. = cos 0 = 1

Inductive Circuit

current is lagging by 90^0
$\theta = -90^0$
P.F. = cos $(-90^0) = 0$

Capacitive Circuit

current is leading by 90^0
$\theta = 90^0$
P.F. = cos $90^0 = 0$

RESISTIVE, INDUCTIVE & CAPACITIVE EFFECT

FIGURE 3-16

3.2.3. Overhead and Underground Transmission

All current-carrying conductors need insulation, for both safety and proper operation. On overhead transmission (OHT) lines, bare conductors can use the air as insulation up to a certain limit of critical voltage. The earth is a good conductor, making possible the use of the ground as a return conductor in D.C. transmission but precluding the use of the ground as an insulator. Therefore, all underground transmission (UGT) lines must be insulated. The conductor with its outer insulation is called cable.

3.2.3.1. D.C. System

If D.C. transmission is to be used, then it must be decided whether to use overhead or underground transmission. As previously discussed in Section 3.2.1., D.C. transmission (DCT) is not as complex as A.C. transmission (ACT), involving only resistive losses and using only one or two conductors. At the present time, converters and filters are essential for DCT.

Overhead DCT has the disadvantage of aesthetic impact on the landscape. Corona losses and radio and television interference (RI and TVI see Section 4.3.1.3.) are present but not significant.

Other problems associated with underground DCT are insualtion selection, corosion of cable pipe, and heat dissipation and its effect on the soil, which is not fully known at this time. Also, some technological problems, such as polarity reversal (changing from + to -), stress inversion to insulation, and effects on grounding, have not been adequately investigated and require further research. At this time, cost is a major disadvantage for both overhead and underground DCT (see Table 3-4 and Figure 3-9).

3.2.3.2. A.C. System

Transmission in both OHT and UGT, but especially UGT, is more complex using an AC system than a DC system.

In overhead ACT, as the length of the line increases, the inductive and capacitive reactance of the lines also increases, causing larger drops in voltage and current. The phase angle also enlarges, creating additional technical problems. However, as noted previously, research has solved these particular problems for lines up to 765 KV and is continuing for lines up to 1,500 KV.

Operation of high-voltage OHT lines is known to cause social and environmental problems, such as radio and TV interference, audible noise, electrostatic and electromagnetic effects, and electrochemical reactions. These are discussed in detail in Section 4.3. Because of these problems, any decision to use extra-high-voltage (EHV-above 300 KV) OHT lines should be made carefully, and proper design of the line becomes more important.

Underground ACT involves several technical problems including insulation. UGT requires insulation made of paper, rubber, plastic, polyester fabrics or others, which have poor heat

TABLE 3-4

COMPARISON OF UNDERGROUND AND OVERHEAD DC TRANSMISSION LINE COSTS

Line Voltage	Capability-Kw	Line Cost/Mile - $ Underground Unpaved Area	Line Cost/Mile - $ Overhead	Ratio[1] UGT to OHT	Cost/Mile per 100,000 Kw[1] Based on Total Capability Underground	Cost/Mile per 100,000 Kw[1] Based on Total Capability Overhead	Ratio[1] UGT to OHT (100,000 Kw)
200,000	600,000	463,000	82,000	5.6:1	77,000	13,700	5.6:1
400,000	1,200,000	759,000	92,000	8.3:1	63,300	7,700	8.2:1
600,000	2,160,000	1,185,000	109,000	10.9:1	54,900	5,000	11:1

To these costs must be added the conversion equipment and, in the case of underground, the cable terminal cost. The conversion equipment for one line is in the order of $23 to $27 per Kw per terminal.

[1] Computed by Montana Department of Natural Resources and Conservation

Source: FPC 1966

rejection and create a problem of heat dissipation. As a result, cooling agents such as oil or inert gas are required for higher voltages. A second problem is that the insulating material lacks mechanical strength of its own. Therefore, it is customary to insert a metallic sheet (known as a shield or sheath) between UGT insulation to increase the mechanical strength of the cable (Figure 3-17). However, this creates a third problem. At high voltages the distance from the outer surface of the cable to the shield or sheath (which is at earth potential, or near zero voltage) is small (approximately one inch). This small distance is responsible for a continuous flow of so-called "charging current" between the conductor and sheath which serves no useful purpose and causes serious electrical losses. The charging current's magnitude varies directly with the length of the cable and the voltage.

When an AC cable is of such length that the accumulated charging current is equal to the thermal rating (the maximum allowable current) of the cable, then the current output of the cable is reduced to zero unless appropriate compensation is made. The length at which this occurs for a particular cable is known as the critical length of that cable. Table 3-5 gives critical length, in miles, of uncompensated lines at several voltage levels.

TABLE 3-5

CRITICAL LENGTH IN MILES
OF UNCOMPENSATED LINES

KV	69	138	230	345	(500)
Critical Length (C.L.)	55	41	38	26	(16)

For more detail, see Appendix I4.

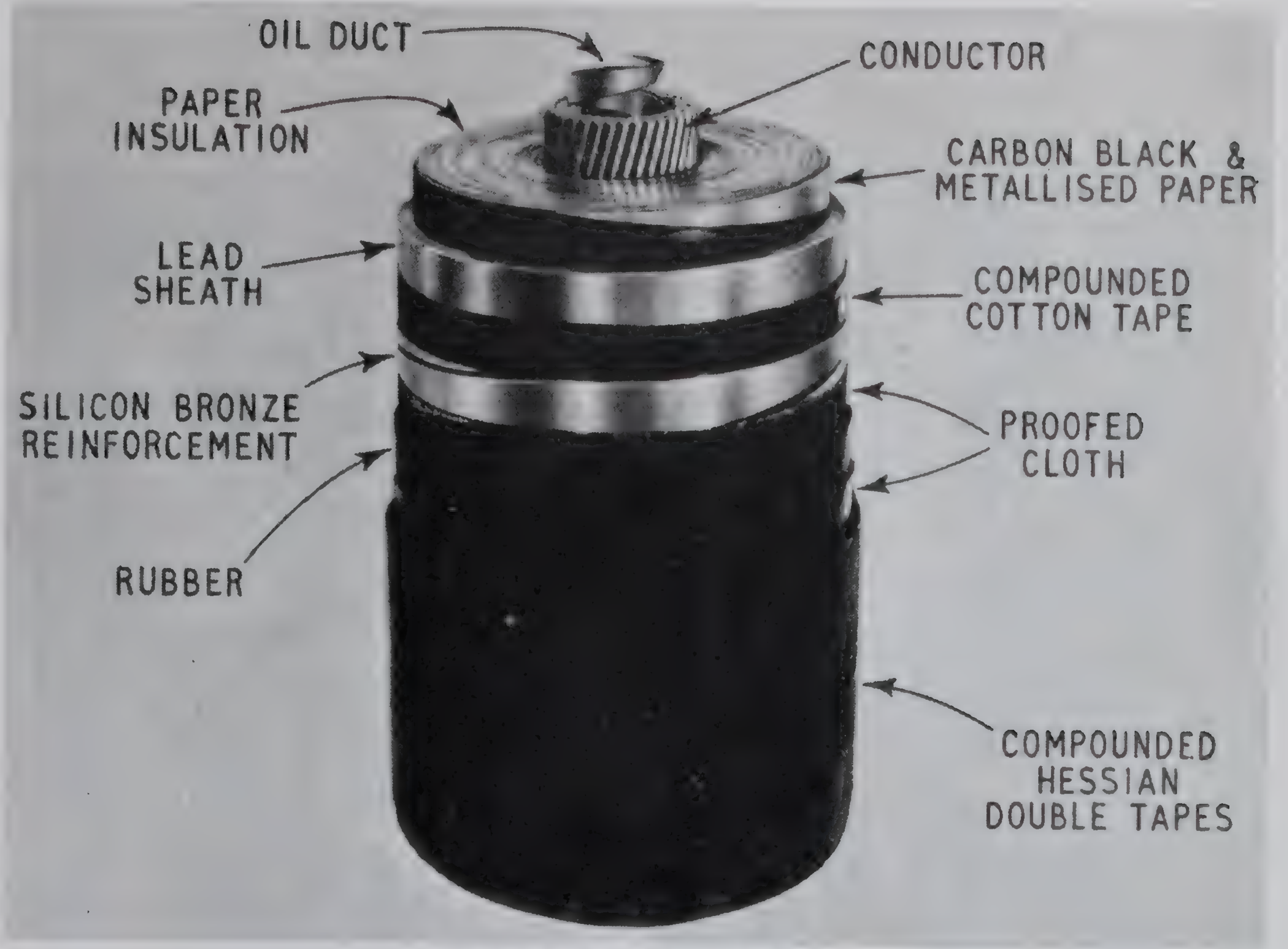
Further problems in UGT which require special attention are corrosion, leakage at joints of the cooling agent in the cable, heat dissipation, and fault detection. Other phenomena such as skin effect, dielectric losses, corona effects, and electrical stress must also be confronted (see glossary). For UGT fault detection, cathodic protection and other sophisticated procedures and equipment are essential.

Cost is the major reason UGT is not presently practical for long high voltage transmission lines. In addition, a great deal of research, which is not progressing rapidly, is necessary to overcome the technical problems discussed previously. Tables 3-6, 3-7 and 3-8 give cost comparisons of D.C. and A.C. transmission.

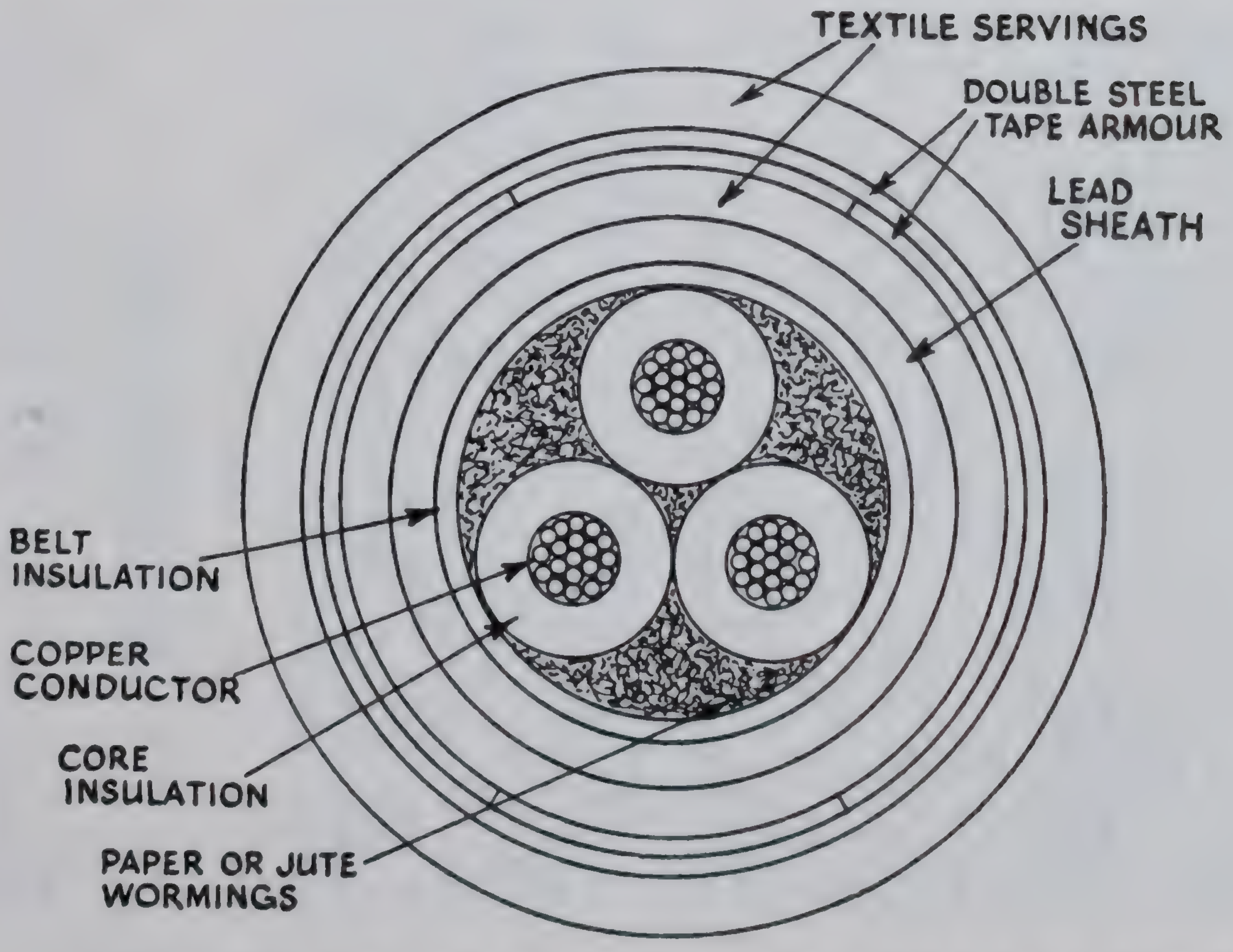
3.2.4. Summary of Cost Values

A comparison of overhead D.C. and A.C. transmission costs for the proposed Colstrip project, which includes two intermediate delivery points shows that D.C. transmission can be three to six times higher (not considering the time element). If the proposed project would extend 430 miles without intermediate tapping, the cost could be 0.9 to 1.9 times higher for D.C. (see Figure 3-9). It should be noted that cost studies require detailed analysis in the initial planning period of a project.

The cost comparison for overhead and underground transmission for this project is shown in Table 3-9 with reference to Tables 3-6 and 3-7.


OIL DUCT
CONDUCTOR
PAPER INSULATION
CARBON BLACK & METALLISED PAPER
LEAD SHEATH
COMPOUNDED COTTON TAPE
SILICON BRONZE REINFORCEMENT
PROOFED CLOTH
RUBBER
COMPOUNDED HESSIAN DOUBLE TAPES

SINGLE PHASE CABLE



CROSS-SECTION OF A THREE-CORE BELTED TYPE CABLE

gur 3- Ba s, I)

TABLE 3-6

TOTAL ESTIMATED COSTS FOR AC & DC HIGH VOLTAGE UNDERGROUND TRANSMISSION LINES WITH PIPE TYPE CABLE

(Exclusive of compensation, conversion, sectionalizing, and terminal cost)

					Total Installed Cost Per Mile - $1,000[1]			
					Average Street Cond. (Suburban)		Unpaved Area (Rural)	
Operating Voltage KV	Copper Cond. Size MCM	Pipe Size In.	No. of Cir. in Common Trench	Nominal Thermal Cap MVA[2]	Reported Range	Adjusted Average	Reported Range	Adjusted Average
3 Ø A-C								
69	2000	6-5/8"	1	118	269 - 442	342	219 - 402	316
69	2000		2	208	468 - 750	614	418 - 728	562
138	2000	8-5/8"	1	227	300 - 496	428	248 - 454	369
138	2000		2	392	556 - 896	764	472 - 822	674
230	2000	10-3/4"	1	371	376 - 661	552	319 - 629	498
230	2000		2	638	702 - 1164	1010	612 - 1120	908
345	2000	10-3/4"	1	500	464 - 806	657	407 - 774	591
345	2000		2	814	878 - 1442	1216	788 - 1390	1102
500	2000	10-3/4"	1	790	688 - 1005	862	631 - 972	818
500	2000		2	1316	1326 - 1842	1616	1236 - 1764	1532
D-C								
± 200	900	6-5/8"	2	600 MW	473 - 765	593	390 - 568	463
± 400	1000	8-5/8"	2	1200 MW	709 - 1104	885	622 - 936	759
± 600	1500	10-3/4"	2	2160 MW	1056 - 1592	1341	965 - 1560	1185

[1] Fixed terminal costs, not included here, are shown on Table 3-7. Engineering and overhead costs are included in the various items. Limits of ranges shown here do not exactly equal the sum of corresponding limits shown on Table 3-7 because of variations in breakdowns between reporting companies. All costs are in 1965 prices and dollar values.

[2] Rating in MVA is based on summer normal conditions of 75% load factor, 25°C underground ambient, 90 thermal ohms, 3 ft. cover, 24" center line pipe spacing, 75°C copper temp. Paper insulation except 500 Kv cable which is assumed to be synthetic insulation. DC terminal equipment based on valve ratings.

Source: FPC 1966

TABLE 3-7

ESTIMATED COSTS FOR HIGH VOLTAGE UNDERGROUND TRANSMISSION WITH PIPE-TYPE HIGH PRESSURE OIL-FILLED CABLE

Operating Voltage KV	Copper Cond. Size MCM	Pipe Size In.	No. of Cir. in Common Trench	Nominal Thermal Rating MVA[1]	Fixed Terminal Cost[2]	Material Cost Per Mile[3]	Installation Cost/Mile[4]	
							Average Street Conditions (Suburban)	Unpaved Area[5] (Rural)
Alternating Current Lines								
69	2000	6-5/8	1	118	69-98	142-227	125-291	76-251
69	2000		2	208	134-196	284-454	174-494	132-426
138	2000	8-5/8	1	227	90-127	162-251	140-324	86-282
138	2000		2	392	170-254	324-502	230-552	148-478
230	2000	10-3/4	1	371	134-170	229-331	155-382	98-350
230	2000		2	638	254-340	458-662	260-652	170-574
345	2000	10-3/4	1	500	152-207	300-406	161-465	107-430
345	2000		2	814	304-390	600-812	274-750	174-700
500	2000	10-3/4	1	790	193-258	520-600	167-520	109-485
500	2000		2	1316	386-504	1040-1200	284-850	178-760
Direct Current Lines								
±200	900	6-5/8	2	600	82-248	243-285	230-505	145-285
±400	1000	8-5/8	2	1200	116-390	442-530	253-634	166-410
±600	1500	10-3/4	2	2160	156-502	771-795	275-800	175-770

[1] Rating in MVA is based on summer normal conditions of 75% load factor, 25°C underground ambient, 90 thermal ohms, 3 ft. cover, 24" center line pipe spacing, 75°C copper temp. Paper insulation except 500 Kv cable which is assumed to be synthetic insulation. DC terminal equipment based on valve ratings.

[2] Includes labor and material for 2 terminals consisting of single conductor potheads and structure, cable from trifurcator to pothead, one oil pressurizing plant and cathodic protection.

[3] Includes pipe, cable, manholes, oil and joining material, sales tax and stores or handling charges.

[4] Includes all labor costs for installing pipe and cable, making joints and oil filling. The second circuit is assumed to be in the same trench but no other circuits within 15'.

[5] Right-of-way costs, if any, were reported in this item.

General: Engineering and overhead costs are included in the various items. All costs are in 1965 prices and dollar values.

Source: FPC 1966

TABLE 3-8

RANGE OF ESTIMATED COSTS PER MILE FOR HIGH VOLTAGE OVERHEAD TRANSMISSION LINES
(Exclusive of compensation, conversion, terminal, and transformation cost)

Oper. Volt. KV	ACSR Cond. Size MCM	Nominal Summer Thermal Rating MVA[1]	No. of Circuits & Structure Material[2]	Reported Range of Material Cost/Mi. $1000[3]	Reported Range of Labor Cost/Mi. - $1000		Reported Range of Right-of-Way $1000/Mi.[6]	Total Cost/Mi. - $1000	
					Foundations[4]	Tower Erection and Stringing[5]		Reported Range	Adjusted Average
Alternating Current Lines									
69	1-477	75	1-W	6.5-23.0	0-24.0	5.9-24.0	0-38.0	19.8-86.0	50.8
	1-795	105	1-W	9.4-23.5	0-26.0	7.7-30.0	0-38.0	23.4-100.0	50.9
	1-795	105	1-S	13.2-28.0	3.0-38.0	9.6-36.0	7.1-38.0	34.9-122.0	66.2
	1-795	210	2-S	22.7-36.0	5.0-48.0	16.9-60.6	7.1-38.0	51.3-170.0	87.8
138	1-477	150	1-W	8.9-25.0	0-26.0	7.3-20.0	7.5-46.0	35.2-94.1	65.4
	1-795	210	1-W	11.3-26.0	0-26.0	8.4-36.0	7.5-46.0	32.2-111.0	60.7
	1-795	210	1-S	14.4-30.0	3.6-42.0	11.4-42.0	7.5-46.0	36.9-136.0	73.0
	1-795	420	2-S	25.6-42.0	5.3-51.0	16.9-66.0	7.5-46.0	54.4-184.0	97.0
230	1-954	385	1-W	11.8-29.0	0-20.0	9.3-43.0	7.7-52.0	33.5-124.0	75.2
	1-1431	490	1-S	20.5-45.0	4.0-53.0	12.1-58.0	7.9-52.0	44.3-173.0	94.1
	1-1431	980	2-S	31.0-60.0	5.7-64.0	17.1-90.0	7.7-52.0	61.6-237.0	128.4
345	2-795	1050	1-W	25.0-36.5	0-20.0	14.4-54.0	11.6-57.0	63.9-147.0	91.8
	2-795	1050	1-S	24.5-56.0	4.0-38.0	15.6-57.0	8.0-57.0	52.5-171.0	101.7
	2-1590	3160	2-S	45.0-106.0	5.7-93.0	26.0-159.0	7.9-57.0	85.1-393.0	183.5
500	2-1780	2470	1-S	36.3-72.0	4.4-72.0	26.6-120.0	9.3-64.0	76.5-306.0	155.1
700	4-954	4700	1-S	78.0-93.6	5.6-84.0	41.8-168.0	15.9-76.0	164.5-387.0	199.4

Continued on following page

Table 3-8 Continued

Oper. Volt. KV	ASCR Cond. Size MCM	Nominal Summer Thermal Rating MVA[1]	No. of Circuits & Structure Material[2]	Reported Range of Material Cost/Mi. $1000[3]	Reported Range of Labor Cost/Mi. - $1000		Reported Range of Right-of-Way $1000/Mi.[6]	Total Cost/Mi. - $1000	
					Foundations[4]	Tower Erection and Stringing[5]		Reported Range	Adjusted Average
Direct Current Lines									
200	2-1590	600	1-S	31.6-43.0	5.7-26.0	21.0-54.0	10.4-33.8	71.9-151.0	94.8
400	2-1590	1200	1-S	26.6-48.0	3.9-30.0	19.6-57.0	11.8-40.5	58.2-160.0	95.7
600	2-1590	2160	1-S	43.2-62.6	5.9-34.0	27.7-60.0	13.0-47.5	94.0-176.0	129.0

[1] Based on 85°C conductor and 40°C ambient air temperature plus solar heating, 2.0 fps wind velocity and .5 emmissivity coef. Terminal equipment based on 1500 ampere valve ratings for 200 and 400 kilovolts, and 1800 amperes for 600 kilovolts.

[2] 1 = one circuit on single circuit tower, 2 = two circuits on double circuit tower, W = wood pole, S = steel tower.

[3] Includes structure, insulators, conductors, fittings, and all other materials including foundation material, sales tax and stores or handling charges. Does not include transformer cost.

[4] Includes all foundation installation, surveying, grounding and any necessary construction roads.

[5] Includes all costs of assembling the material into a complete line.

[6] Includes property and clearing costs for 60% of right-of-way. R/W widths 69 kv-ac-75 ft.; 138 kv-ac-100 ft.; 230 kv-ac and 200 kv-dc-125 ft. 345 kv-ac and 400 kv-dc-150 ft.; 500 kv-ac and 600 kv-dc-175 ft.; 700 kv-ac-225 ft.

General - Engineering and overhead Costs are included in the various items. Limits of ranges on individual items do not exactly equal the sum of the corresponding limits because of vatiations in break downs because of reporting companies. All costs are in 1965 prices and dollar values.

Source: FPC 1966

TABLE 3-9

COST COMPARISON OF OVERHEAD AND UNDERGROUND TRANSMISSION FOR THE COLSTRIP PROJECT

		Cost of OHT ($000 Per Mile)	Average Cost	Cost of UGT ($000 Per Mile	Average Cost	Ratio
A.C.	500 KV System	76.5--306	155.1	637-972	818	5.27
D.C.	±400 KV System (which can be equivalent to 500 KV without tapping)	58 --160	95.7	622-936	759	7.93

3.2.4.1. Expected Technological Development

The following is a summary of expected changes in transmission technology in coming years (Denbrock 1972).

3.2.4.2. Changes Expected In Three Years

765 KV lines may become more common. UGT lines will be considered more seriously, and aesthetics will be of greater importance in planning (tower design, corridor selection, etc). SF_6 (a cooling liquid) will be extended to 500 KV for use in UGT.

3.2.4.3. Changes Expected in Five Years

765 KV lines will become prevalent, and UGT lines will become more common. Synthetic materials, inert gases and different vacuum devices may be used in cable insulation.

3.2.4.4. Changes Expected in 10 Years

1,100 and 1,300 KV lines will be used. Simplified control will be obtained by using fiber optics, lasers, and cryogenic gases in cables. Superconductivity will be given more importance.

3.2.4.5. Changes Expected In 20 Years

Use of OHT will be reduced and when practiced, may be by microwave. Mini powerplants, fuel cells, and radioisotopes will probably be used as local energy sources, thus reducing the need for transmission lines.

Tables 3-10 and 3-11 show expected additions in EHV transmission and the cost of research projects, respectively.

3.3. Existing Transmission Systems

Transmission lines are highways for transporting large blocks of electrical energy. Interconnection of these lines, which forms a "grid", has advantages and disadvantages in much the same way that the interconnection of our interstate highway system results in the advantages of saving time and fuel and the disadvantages of increased localized impacts and greater accident risk and magnitude. Some of these advantages are discussed in Section 3.1.

In the grid system, the flow of current in each line is dependent on the total system demand, which is a time variable. When a fault occurs on a line, due to natural occurrences such as lightning, earthquake, gusty wind, hail, or human caused damages, the load normally carried by that line must be borne by other lines. To determine whether lines in a system are capable of bearing this extra load, it is necessary to study load flow--the flow of power in the entire

TABLE 3-10

Projected EHV Transmission Line Additions in Miles

(For U.S.A.)

Period	345 KV	500 KV	765 KV	1100-1300 KV	1500 KV
Up to 1970 (Existing or Authorized)	16,600	7,500	560	-	-
1972	3,341	1,662	130	-	-
1973	2,640	772	134	-	-
1974	2,584	1,516	256	-	-
1975	2,701	623	250	-	-
1976	1,740	599	400	200	-
1977-80	6,000	3,000	1,000	400	-
1980-90	15,000	9,000	8,000	1,000	1,000
1990-2000	18,000	10,000	9,000	2,000	1,500

(Denbrock 1972)

TABLE 3-11

Expected Cost (between 1972-2000) of Development ($Millions) of Particular Transmission and Distribution Research Projects

(Electric Research Council)

AC Underground Transmission	AC Overhead Transmission	DC Transmission	Distribution	Bulk Power Substations	System Security & Control
$665.7	$305.2	$451.2	$155.3	$444.1	$172.1

(Denbrock 1972)

grid system at a particular moment considering the faults. Besides the overloading of operative lines in the event of a fault, momentary overloading of connected generators occurs. A detailed study of system stability is necessary to determine whether the overloaded generators can maintain stability (remain in operation).

Stability may be defined as that attribute of the power system which enables it to develop restoring forces equal to or greater than the distrubing forces, so as to maintain a state of equilibrium. The stability problem in the transmission of electrical energy can be compared to a system that uses a belt to drive a wheel bearing a load on its shaft. If the load is increased suddenly, the force of the load may be greater than the friction between the wheel and the belt, causing the belt to slip and the system to fail. Loads in high voltage transmission can be of two types: sudden loads which create transient stability problems, and operational loads which can create steady-state stability problems.

For further discussion of the stability problem, see Appendix I1.

3.3.1. Montana Transmission Grid System

Existing transmission lines in Montana (see Section 5.2.1.1.) are interconnected in three directions, east, south, and west. The state is between two giant grid systems, one administered by the Western Systems Coordinating Council (WSCC) and the other by the Mid-Central Area Reliability Council Agreement (MARCA). If Colstrip is developed, the Department of the Interior may want to connect the grids of the western and central regions of the United States. A study is presently being conducted to determine the feasibility of interconnection. At this time a 230 KV line from Yellowtail Dam to North Dakota is the system intertie, but it is "opened" (by the circuit breaker) due to system weakness and instability. To close this intertie, new East-West H.V. transmission in Montana will be needed. Presently, Montana can satisfy its own needs with a grid system composed of 230 KV lines, but if development of the state's vast coal reserves results in growth of electric energy production, for distant loads, more and more lines, with greater KV ratings, will be needed.

Eastern Montana is mainly served by power plants owned by Montana-Dakota Utilities (MDU) and the Bureau of Reclamation (BR). Central Montana is served by MPC, and the western part of the state by MPC, Pacific Power and Light Company (PP&LC), and federal agencies, including BR and BPA. Twenty-five cooperatives, members of the Rural Electric Cooperatives Association (REA) are responsible (along with PP&LC and MPC) for distribution of electrical power in Montana.

3.3.2. Northwest Grid System

Montana is included in the Northwest Grid System (Northwest Power Pool) which in turn is included in the Western Grid System (see map located in Volume 2, Chapter 4). One of the principal federal agencies involved with the Northwest Grid System is the BPA, created by the

Bonneville Power Act signed by President Roosevelt on August 20, 1937, which directs the BPA administrator to:

1) Sell at wholesale the electric energy from Bonneville Dam. (Today there are 27 federal dams under the authority of the BPA, four more under construction, and two authorized but not yet begun. Federal dams are constructed by the Army Corps of Engineers and BR. They proivde flood and pollution control, aid in navigation, provide water for irrigation, recreation, industry, and municipal water systems and generate electrical power).

2) Construct, operate, and maintain transmission lines and substations.

3) Interconnect the Bonneville project with other federal projects and publicly owned power systems.

BPA is attempting to build the largest 500 KV grid system in the United States to overlay its present lower voltage transmission system. The proposed Colstrip-Hot Springs 500 KV line would tie into that system and be compatible with it.

"Rapid population and industrial growth in the Northwest coast area and delay in construction of nuclear power plants in that area, are an important reason for the recent surge of interest in using coal from eastern Montana and building two 700 MW power plants." This statement was made in a public meeting in Helena on July 17, 1974 by an MPC engineer. However, according to the WSCC 1974 report for peak demand and supply of Northwest System, the margin of electricity (see Appendix I5) available for peak will be increasing (see Table 3-12).

3.3.3. Western Transmission Grid System

Because of the 1965 Northeast blackout, and the massive break-up of the Northeast interconnected grid system, the National Electric Reliability Council (NERC) was formed in 1966. The Western Systems Coordinating Council (WSCC or Western Systems), a regional reliability council subordinate to NERC, was formed in March of 1967 with forty signatories representing electric power systems engaged in bulk power generation and/or transmission. Fourteen western states were represented, along with British Columbia (see Figure 3-18). Eight other regional councils were formed in the United States. The main purposes of these councils are to reduce installation of reserve generating capacity, create the ability between systems to share power, improve generation and transmission of power under emergency outages, and provide a safe, interconnected system.

The WSCC region is characterized by extreme variations in population densities and electrical load densities, and extreme distances between load centers and power generating sources. The geogrpahical area administered by WSCC is subdivided into four sections. The WSCC technical staff, implemented in 1972, has established headquarters in Salt Lake City, Utah.

TABLE 3-12
NORTHWEST POWER POOL

Including: Bonneville Power Administration, B.C. Hydro and Power Authority, Chelan County PUD, Cowlitz County PUD, Douglas County PUD, Eugene Water and Electric Board, Grant County PUD, Idaho Power Co., Montana Power Co., Pacific Power and Light Co., Portland General Electric Co., Puget Sound Power and Light Co., Seattle City Light, Tacoma City Light, U.S. Corps, of Engineers (No. Pac. Div.), U.S. Bureau of Reclamation (NW Region), Utah Power and Light Co., Washington Water Power Co., West Kootenay Power and Light Co., and other small non-member systems in the Pool Area.

Period and Condition		Firm Load	+ Net Resources Transfers	Resources on Maintenance Status	Margin[1/]	
Year	Month	MW	MW	MW	MW	%
1974 Adverse Hydro	August Peak	23124	28300	1803	5176	22.4
	December Peak	29567	31619	420	2052	6.9
1975 Adverse Hydro	August Peak	24580	31444	1885	6864	27.9
	December Peak	31528	35363	463	3835	12.2
1976 Adverse Hydro	August Peak	26594	34477	1971	7883	29.6
	December Peak	34009	39728	500	4719	13.9
1977 Adverse Hydro	August Peak	28320	37636	2078	9316	32.9
	December Peak	36396	42066	530	5670	15.6
1978 Adverse Hydro	August Peak	30280	44682	2331	14402	47.6
	December Peak	39772	50023	574	11251	29.0

[1/] See Appendix I5

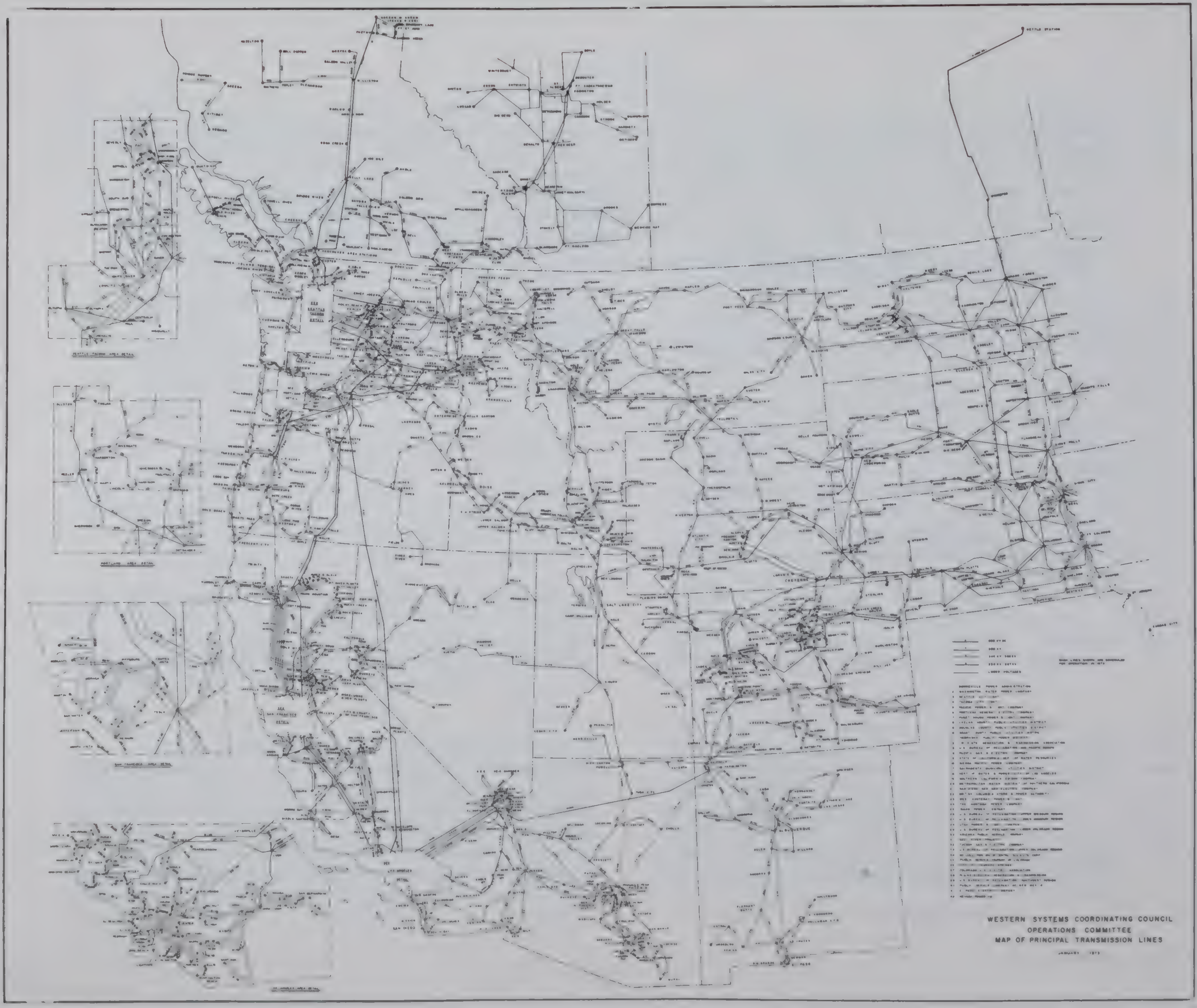

WESTERN SYSTEMS COORDINATING COUNCIL
OPERATIONS COMMITTEE
MAP OF PRINCIPAL TRANSMISSION LINES
JANUARY 1973
SAN FRANCISCO AREA DETAIL
LOS ANGELES
SAN DIEGO
SALT LAKE CITY
CHEYENNE
ALBUQUERQUE

Figure 3-18

WSCC has developed the following reliability criteria for system designs:

1) Limits on the effect of a disturbance in one system on the performance of a neighboring system (should be built in to all systems).

2) Each system will construct or contract for sufficienct transmission capacity to transmit its power reliably without dependence on any other system.

3) Each system must demonstrate stability for a three-phase fault and loss of a single transmission element, or for - single-phase-to-ground fault and breaker failure. This requirement was modified in 1972 to include performance standards for single-phase-to-ground faults with breaker failure and automatic reclosing (WSCC 1974).

4) Administrators of each system are responsible for all planning for that system. WSCC's Planning Coordination Committee reviews individual plans to determine their effects on the entire network.

Table 3-13 provides margins of electricity for the entire system.

3.4. Engineering Alternatives for Colstrip Project

3.4.1. General Discussion

The Colstrip project, since it involves bulk power generation and transmission, is subject to WSCC reliability criteria (see Section 3.3.3.). MPC, in their projected 25-year load forecast (see Figure 3-19), indicates that Montana can utilize all MPC generating capacity including the Colstrip complex by 1997. Projected peak load for that year, according to the MPC load forecast table, will be 2789 MW. Average load in 1997 will be 1868 MW.

Table 3-14 provides MPC's future peak load growth predictions for Montana's major load centers, in multiples of the 1975 peak load (see also Figures 3-20 and 3-21).

TABLE 3-14

Load Center	1975	1980	1990	2010
Missoula	1	1.29	1.88	3.86
Great Falls	1	1.31	2.25	4.50
Helena	1	1.26	2.02	4.05
Butte-Anaconda	1	1.16	1.56	3.13
Bozeman	1	1.27	2.03	4.05
Lewistown	1	1.22	1.83	3.66
Billings	1	1.34	2.39	4.80

(MPC unpublished)

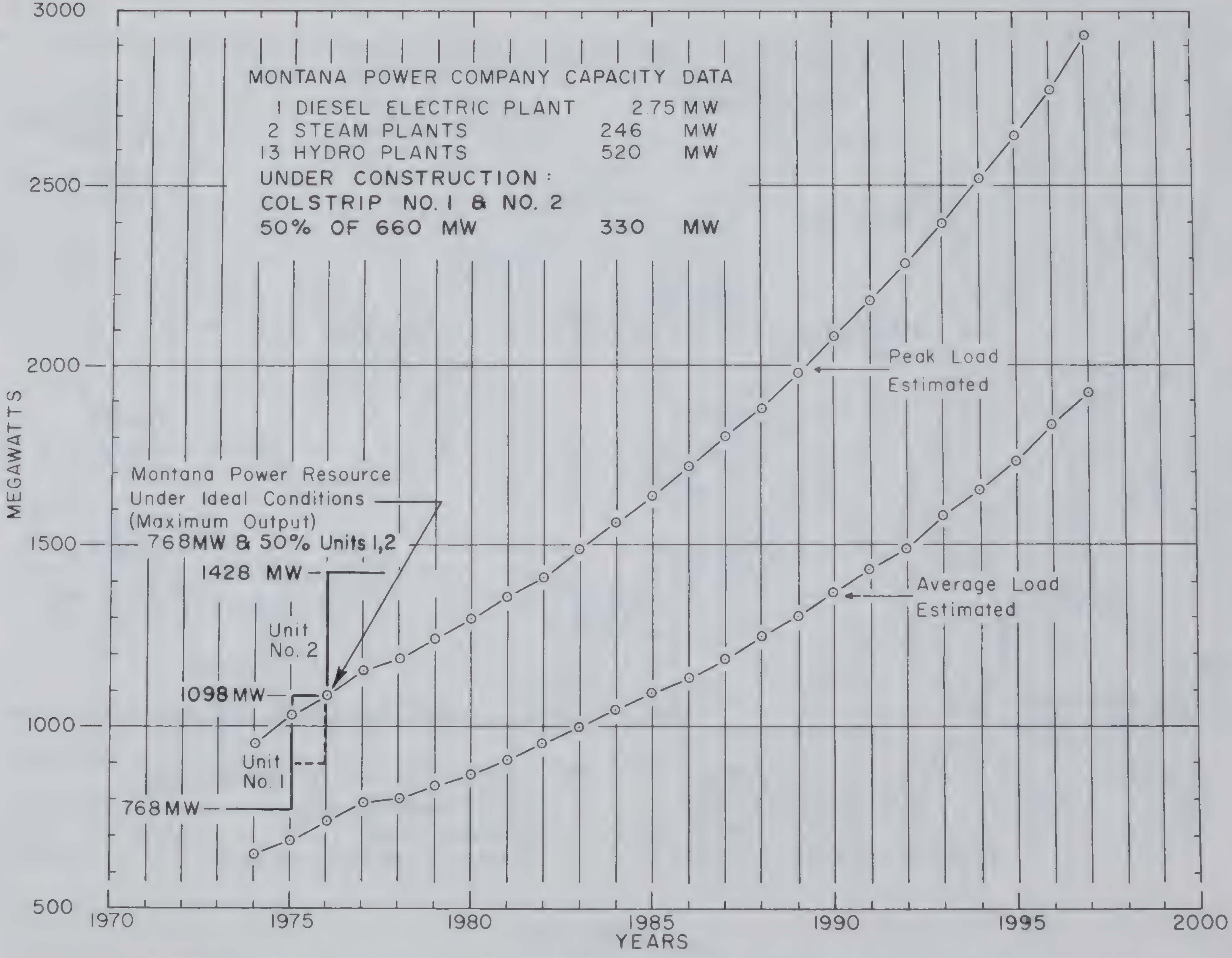
Delivery of power to intermediate load centers such as Billings, Helena and Butte would require tapping of the transmission lines near the load centers. D.C. transmission (see Section 3.2.2.), because it requires converters at generators and power delivery points, is more costly, and the installation and operation of additional converters at these load centers would greatly

Table 3-13

The indicated August and December capacity margins for the WSCC area are summarized below assuming adverse hydro conditions:

Reserve Margins (R.M.)

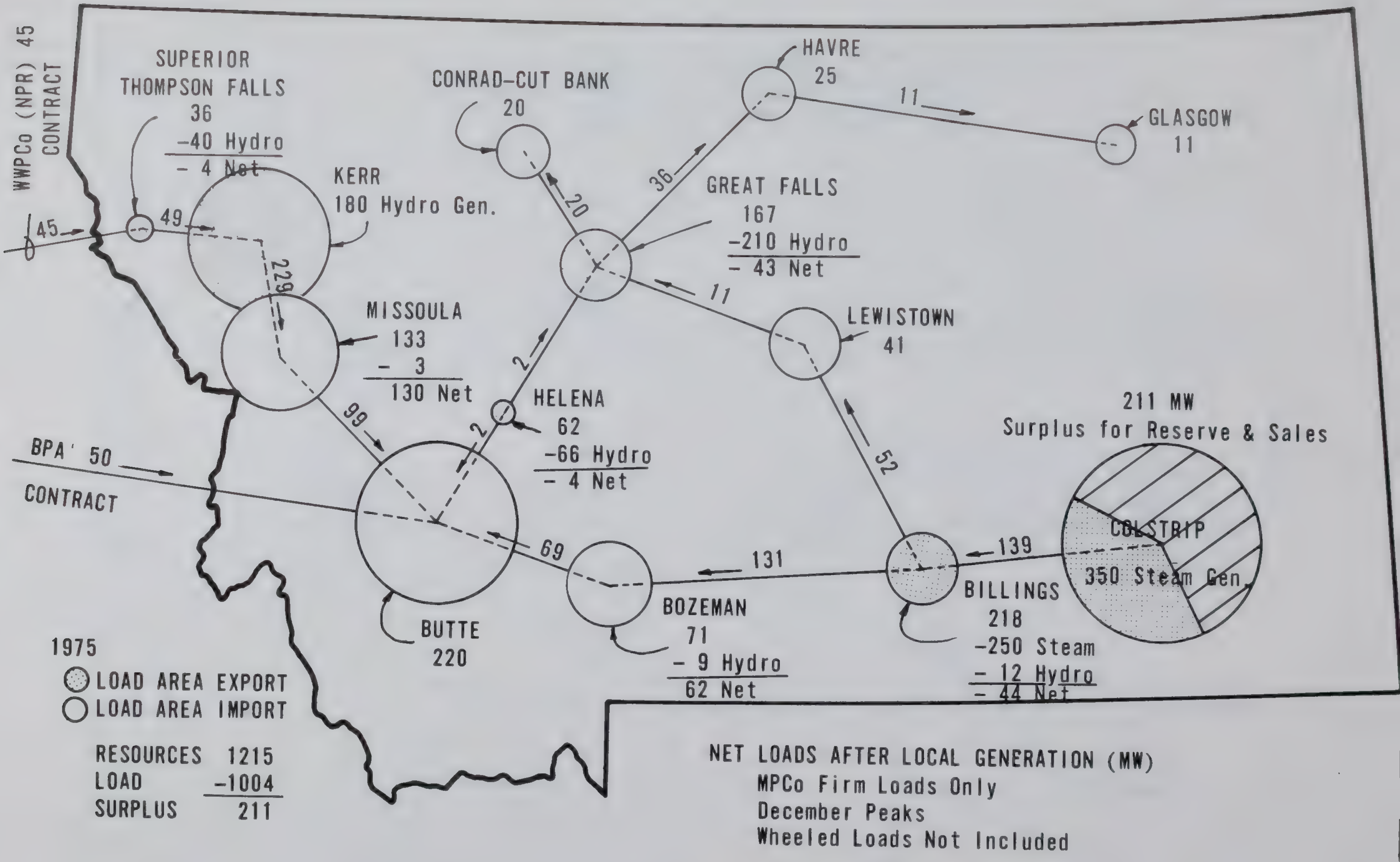
	August		December	
Year	MW	R.M. % of Peak	MW	R.M. % of Peak
1974	13,589	20.4	12,964	18.6
1975	17,074	24.0	15,966	21.5
1976	20,272	26.4	18,931	23.7
1977	20,941	25.6	19,588	22.9
1978	26,335	30.0	26,301	28.8



MONTANA POWER COMPANY'S ESTIMATED LOAD GROWTH

From M. P. C. Long Range Plan of 25 Years

Figure 3-19



RESOURCES		1215
LOAD		-1004
SURPLUS		211

NET LOADS AFTER LOCAL GENERATION (MW)
MPCo Firm Loads Only
December Peaks
Wheeled Loads Not Included

FIGURE 3-20

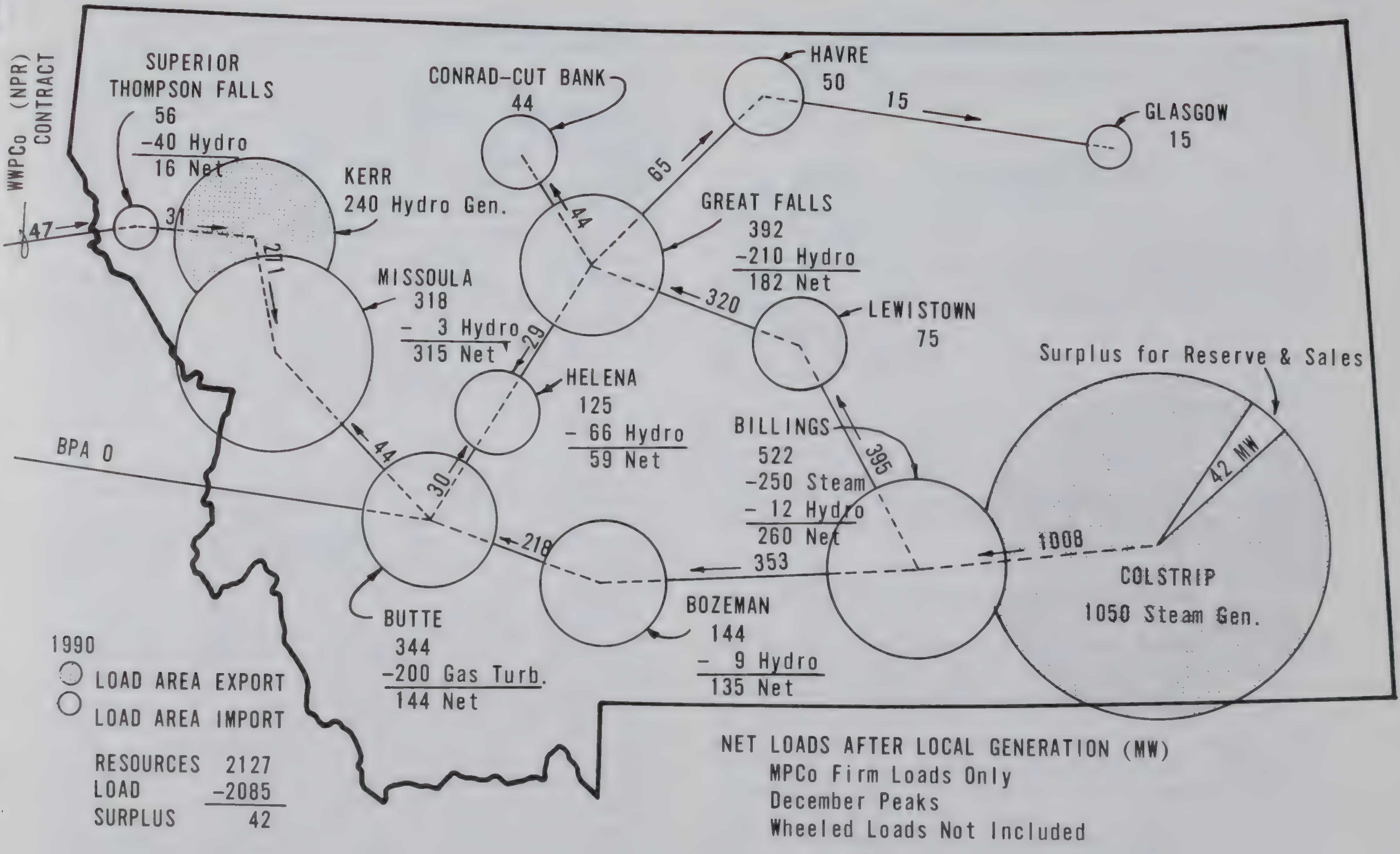

WWPCo (NPR)
CONTRACT
47
SUPERIOR
THOMPSON FALLS
56
-40 Hydro
16 Net
31
KERR
240 Hydro Gen.
201
CONRAD-CUT BANK
44
44
HAVRE
50
15
GLASGOW
15
65
GREAT FALLS
392
-210 Hydro
182 Net
MISSOULA
318
- 3 Hydro
315 Net
29
320
LEWISTOWN
75
HELENA
125
- 66 Hydro
59 Net
Surplus for Reserve & Sales
BILLINGS
522
-250 Steam
- 12 Hydro
260 Net
395
42 MW
BPA 0
44
30
218
1008
353
COLSTRIP
1050 Steam Gen.
BUTTE
344
-200 Gas Turb.
144 Net
BOZEMAN
144
- 9 Hydro
135 Net
1990
LOAD AREA EXPORT
LOAD AREA IMPORT
RESOURCES 2127
LOAD -2085
SURPLUS 42
NET LOADS AFTER LOCAL GENERATION (MW)
MPCo Firm Loads Only
December Peaks
Wheeled Loads Not Included

FIGURE 3-21

increase the cost. For this reason, D.C. transmission has been ruled out by the applicants.

3.4.1.1. Power Delivery Point

For the integration of Colstrip plants into the WSCC system several power delivery points were considered by BPA as well as by the applicants (Wilkerson 1974) The direct route from Colstrip to Portland (Costrander Substation; Figure 3-18) which is 820 miles long can be made feasible from an engineering standpoint by using a D.C. line.

However, such a line would have to pass through the Magruder Corridor, a strip of land about 15 miles wide located between the 1,240,000 acre Selway Bitterroot Wilderness area in the north and the 217,000 acre Salmon River breaks primitive area to the south.

It is important to realize that the 173,000 acre Magruder Corridor is the subject of an intense development versus preservation controversy. Legislation has been introduced by the Montana congressional delegation to add a large portion of the Corridor, excluding the road, to the National Wilderness Preservation System. The Magruder Corridor contains the headwaters of the Upper Selway River -- an important anadromous fishing stream. In late 1970 the U.S.F.S. declared a 5-year moratorium on development in the Magruder Corridor and is currently conducting detailed land use studies for the area. Until the management status of this controversial area is resolved, construction of a transmission line in the Corridor cannot be considered.

Any route going to the south would be even longer. BPA looked into a D.C. line 940 miles long from Colstrip to Clyde Park (Montana) to midpoint (Idaho) to Malin (Oregon) (Figure 3-18), but considering expense, construction time, and all other disadvantages (see Section 3.2.2.) it is not a viable alternative. For long lines, such as those discussed above, A.C. lines are more expensive and have more losses (see Figure 3-9). Thus, A.C. was not considered. At this time Spokane (Washington) is getting its supply of electricity from coastal plants at Seattle; if Spokane is to be supplied from Colstrip, the flow from Seattle can be made available to Portland, Oregon.

Future tapping between Colstrip and Hot Springs is planned by the applicants to supply Montana's load centers. The 500 KV substation at Hot Springs, owned by BPA, is the western terminal of the proposed line. This substation would be expanded as required by BPA, MPC, and other applicant companies. BPA would need to increase their 500 KV capacity from Hot Springs west; they presently favor building a second 500 KV Hot Springs-Spokane line to augment the existing one. (Power for Spokane would actually be transmitted to the substation at Bell, a few miles north of Spokane, and distributed from there.) Spokane is now receiving its electrical power from the west. Power from Colstrip would displace that flow and supply Spokane, with the overflow being transmitted south to supply Oregon's needs. BPA is conducting a separate environmental impact analysis for their system additions and alternatives.

Four of the five utility companies applying jointly to build Colstrip Units 3 and 4 are west coast companies, and their share of the power generated by the units, proportional to their investment, is about 1300 MW, to be delivered at Hot Springs. If this bulk power were transmitted by a 230 KV system, ten single circuits (lines) would be needed. If a 345 KV system were used, four single circuits would be needed. One 500 KV circuit could carry the amount of power to be transmitted, but considering WSCC's reliability criteria, the applicants have proposed two 500 KV lines.

Because of the limitations discussed in Section 3.2.3., underground A.C. or D.C. transmission are not viable technical alternatives, given the state of existing technology.

3.4.1.2. Criteria for Colstrip Transmission Line Reliability

For the Colstrip-Hot Springs transmission line to provide adequate line reliability, two parallel 500 KV lines have been proposed. No dependable estimate of the number of forced outages that can be expected on these lines can be made, but to increase reliability further it is proposed to divide the lines into three segments each and interconnect them (see Figure 4-1 in Section 4.1., and accompanying text). In the event of a fault on any one segment, the remaining five would carry the total output of the generators. Even if two segments suffer faults, depending on their location, the transmission system might still carry the full load.

3.4.2. Alternative Routes

Four separate route plants for 500 KV transmission from Colstrip to Hot Springs have been considered.

Plan A, shown in Figure 3-22, consists of two 500 KV transmission circuits from Colstrip to Billings to Helena to Hot Springs.

The following load areas are served by the existing 230 KV transmission line system: Billings, Bozeman, Butte-Anaconda, Missoula, Hot Springs and Great Falls.

The 500 KV transmission system would supply step-down transformers in substations near Billings, Helena, and Hot Springs.

Plan B, shown in Figure 3-23, consists of two 500 KV transmission circuits from Colstrip to Billings to Great Falls to Hot Springs.

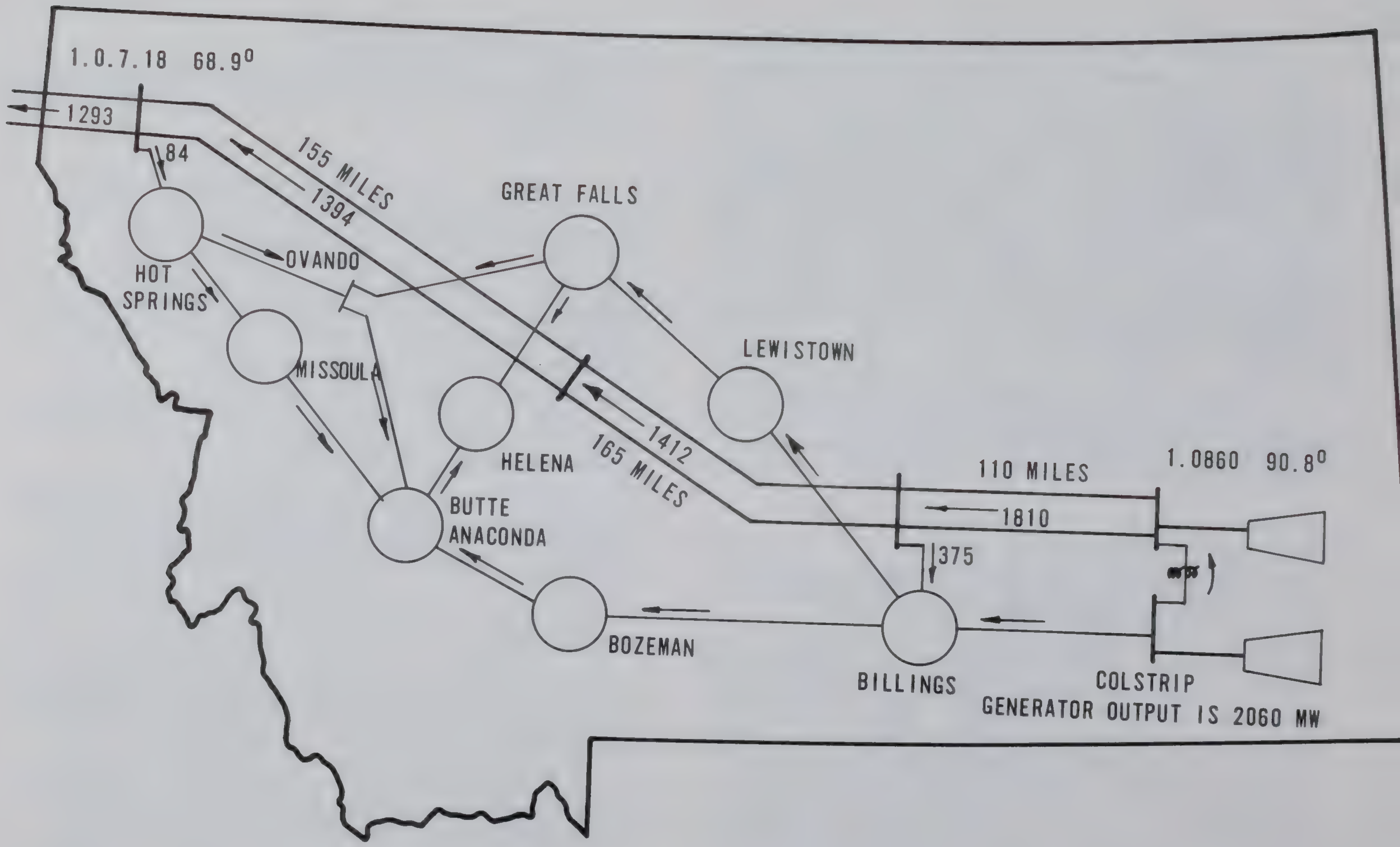
The same load areas as in Plan A are served by the 230 KV transmission line system.

The 500 KV transmission line system would supply step-down transformers in substations near Billings, Great Falls and Hot Springs.

Plan C, shown in Figure 3-24, consists of two 500 KV transmission circuits from Colstrip to Broadview to Butte-Anaconda to Hot Springs.

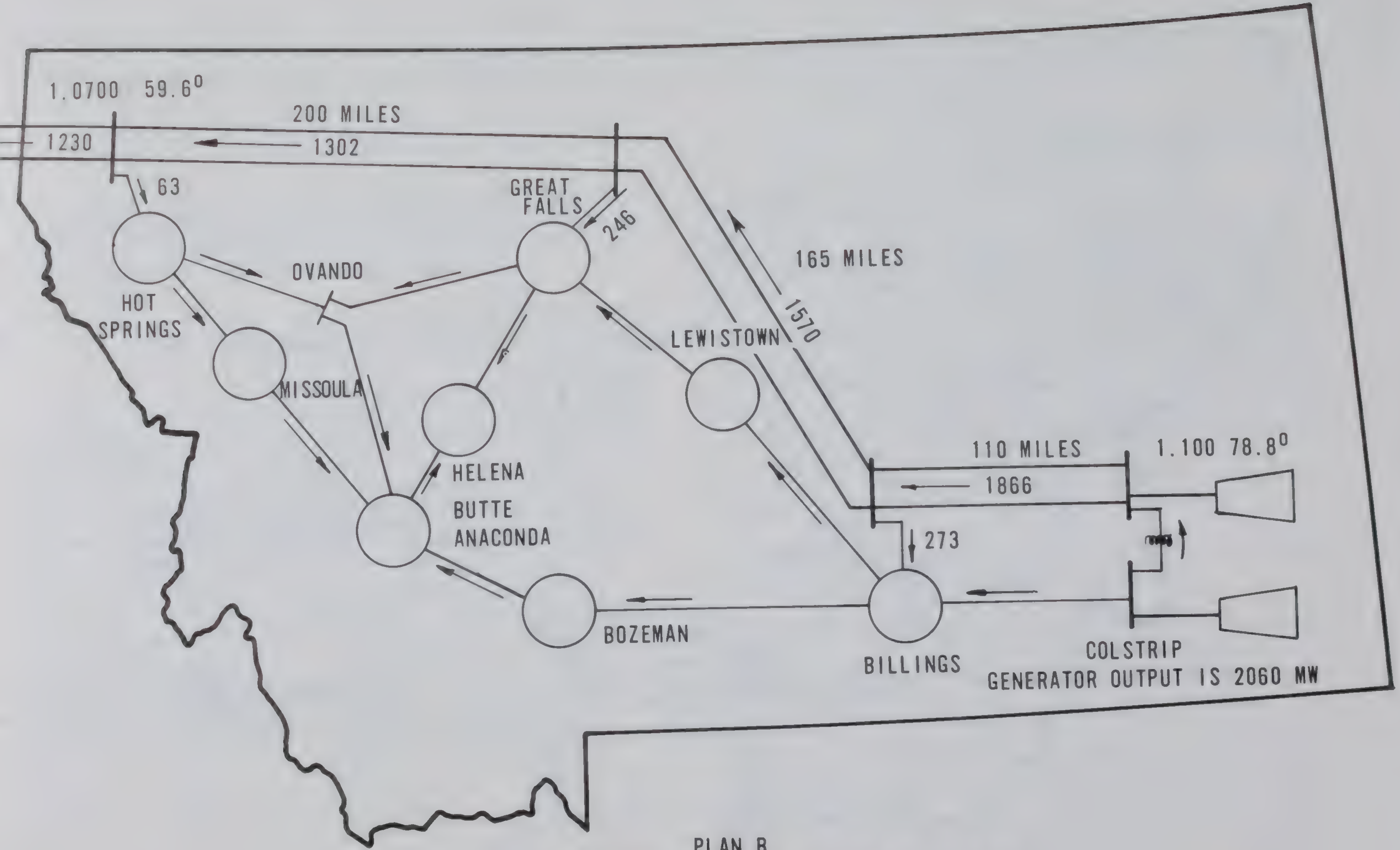
The same load areas as in Plan A are served by the 230 KV transmission line system.

The 500 KV transmission line system would supply step-down transformers in substations near



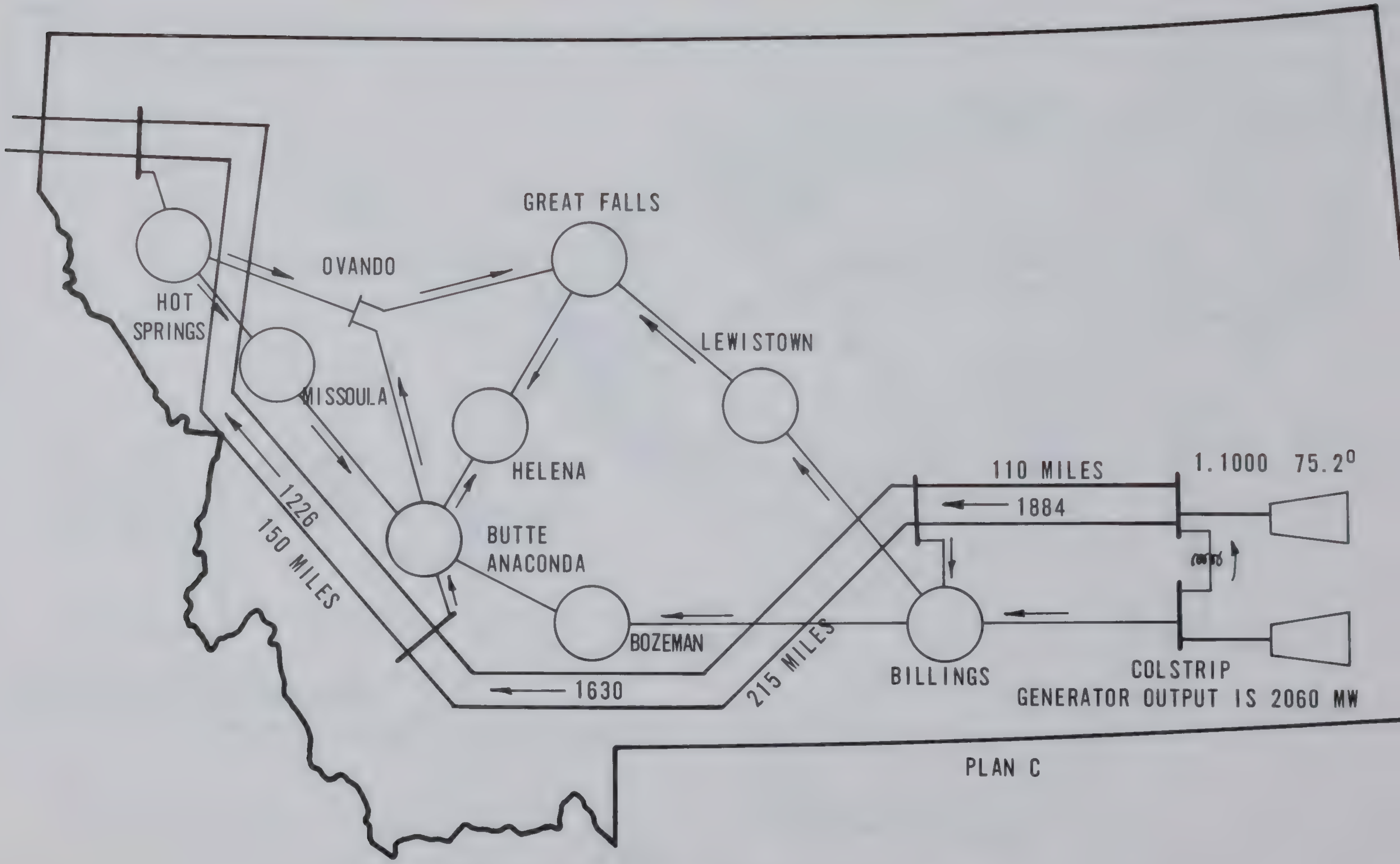
PLAN A
MEGA WATT FLOWS IN 500 KV SYSTEM FOR 1979-80

FIGURE 3-22



PLAN B
MEGA WATT FLOWS IN 500 KV SYSTEM FOR 1979-80

FIGURE 3-23



MEGA WATT FLOWS IN 500 KV SYSTEM FOR 1979-80

FIGURE 3-24

Billings, Butte-Anaconda, and Hot Springs.

Plan D, shown in Figure 3-25, consists of three 500 KV transmission circuits.

One line connects Billings to Hot Springs via Great Falls. A second line connects Billings to Hot Springs via Butte-Anaconda. A third line connects Great Falls to Butte-Anaconda.

The same load areas as in Plan A are served by the 230 KV transmission line system.

The 500 KV transmission line system would supply step-down transformers in the substations near Billings, Great Falls, Butte-Anaconda, and Hot Springs.

A summary of the total 500 KV transmission lines required for the system up to 1990 for each plan is given in Table 3-15.

Table 3-15

	Miles 2 Parallel Circuits	Miles of Single Circuit	Total Miles of Circuit
Plan A	430	---	860
Plan B	475	---	950
Plan C	475	---	950
Plan D	110	870	1,090

Each of the plans have been judged by the following criteria:

1) Ability to transport required megawatts from Colstrip to Hot Springs and maintain a stable system during both normal and abnormal system conditions.

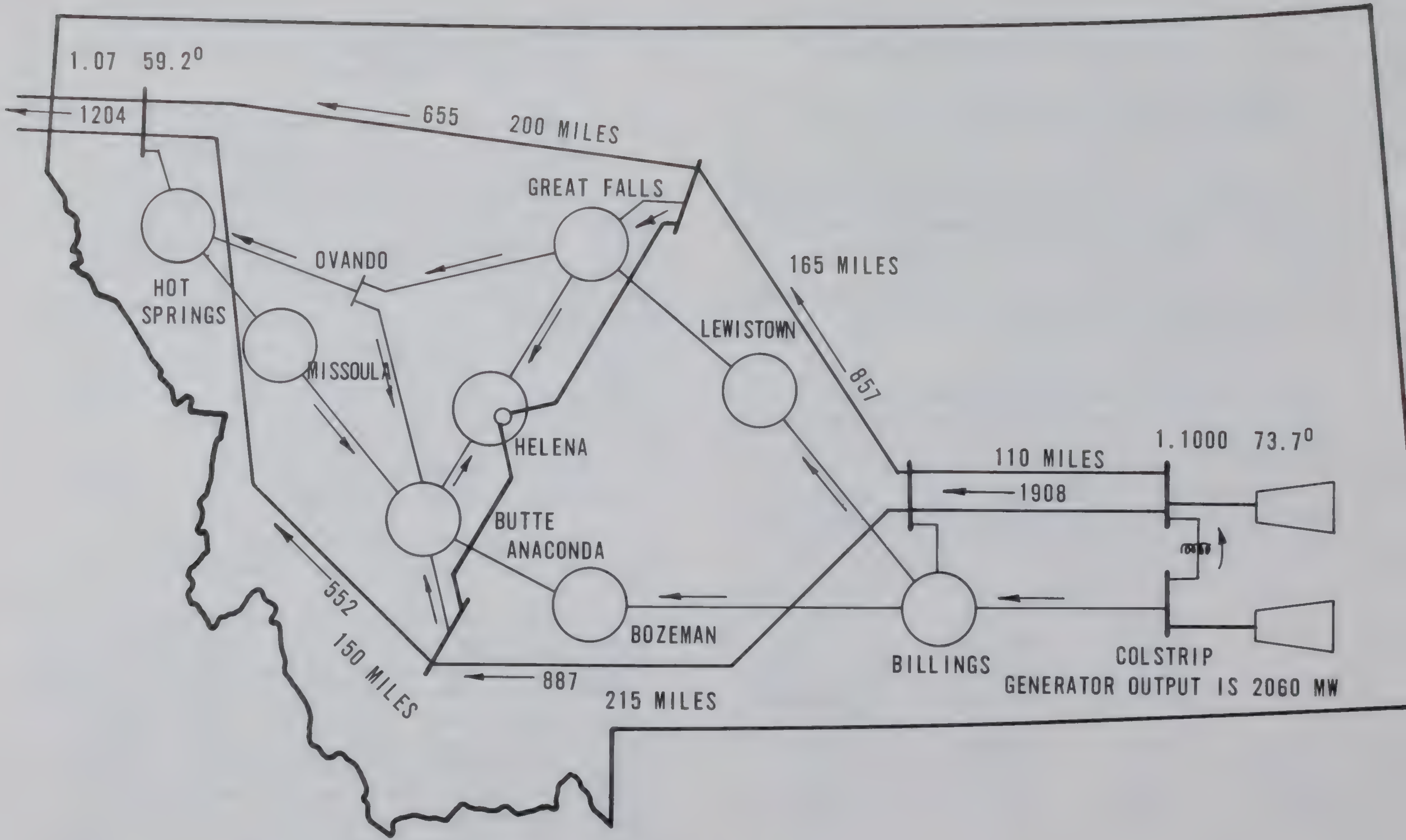
2) Ability to supply major load areas on the MPC system as the MPC load grows.

The applicants have indicated that the stability of Plan A would be acceptable for 1979-1980. Plan B and Plan C can be made as stable as Plan A at an additional cost, either by increasing the amount of series compensation, fast-valving the generator turbines, using breaking resistors, and/or generator dropping. The additional cost involved is small compared to the cost of transmission from Colstrip to Hot Springs and should not be an overriding consideration.

Plan D is not as desirable from a stability standpoint as Plans A, B, or C.

The stability for all plans improves after 1980 due to increased loads in Montana.

Problems associated with subsynchronous resonance (as explained below) may occur with any of the four plans, including the applicants' preferred plan. When capacitors are connected in series with the transmission lines, their installation reduces the transmission line reactance (see glossary) thus increasing the maximum amount of power that the line would carry. The major disadvantage of the use of series compensation is that generators connected to a transmission system with series capacitors may under certain conditions experience subsynchronous resonance. Subsynchronous resonance is an undesirable interaction of the electrical and mechanical systems. It could cause torques in the generator-



PLAN D
MEGA WATT FLOWS IN 500 KV SYSTEM FOR 1979-80
WITH GREAT FALLS - ANACONDA TIE OPEN

FIGURE 3-25

turbine of sufficient magnitude or over a sufficient period of time to damage the generator-turbine. Additional equipment, such as special filters, can prevent these damaging torques.

Engineering studies can determine whether subsynchronous resonance is a problem and identify corrective measures that could be used.

3.5. Optimum Technology Selection

As discussed in previous sections, D.C. transmission or underground transmission are not practical alternatives at this time. Any of the four above-mentioned transmission line routes remain as reasonable and feasible engineering options for the proposed twin 500 KV overhead, A.C. lines. The comparison of routes B, C, and D, with the applicants' preferred route A is based on engineering requirements and economic costs involved. Natural and cultural environmental costs are presented in Chapter 6 on impacts of the proposed line.

A. Plan A (Helena)—Feasible

1. Factors in favor
   - a. Lowest cost
   - b. Stability is best
   - c. Compensation is least (35%)
   - d. Subsynchronous resonance least likely to be a problem
2. Factors against
   - a. Access may be more difficult and costly than Plan B or C
   - b. Maintenance may be more difficult than Plan B or C
   - c. Not immediately adjacent to major projected heavy load centers in Montana
   - d. Passes through heavy earthquake zone (See Section 5.1.1.)

B. Plan B (Great Falls)—Feasible

1. Factors in favor
   - a. Route is accessible
   - b. Maintenance easier than Plan A
   - c. Near one heavy load center
   - d. Passes through minimum earthquake zone
2. Factors against
   - a. Investment cost - greater than Plan A since route is 10.5% longer
   - b. Compensation must be greater (45%), cost would be approximately 13.7% more than Plan A to give adequate stability (also includes -"a"- investment cost)

   c. Subsynchronous resonance more likely than Plan A

C. Plan C (Anaconda)—Feasible

1. Factors in favor

   a. Route is accessible

   b. Maintenance easier than Plan A

   c. Near one heavy load center

   d. Passes through moderate earthquake zone

2. Factors against

   a. Investment cost greater than Plan A. Route is 8.1% longer.

   b. Compensation must be greater to give adequate stability (55%). Cost would be approximately 14% more than Plan A (includes -"a"- investment cost).

   c. Subsynchronous resonance likely since the Billings to Butte-Anaconda link would be 215 miles long compared to the Great Falls to Hot Springs link at 200 miles.

D. Plan D (Butte-Anaconda and Great Falls with a tie between through Helena)--May not be feasible from an engineering standpoint.

Plan A is preferred by the applicants. It has 860 circuit miles of 500 KV transmission. The applicants indicate it would have 35% series capacitor compensation in order to reach acceptable levels of stability.

Plan B has 950 circuit miles of 500 KV transmission, 10.5% more than Plan A. Thus Plan B costs more. The applicants might have to increase the series compensation to 45% on this route to make the stability comparable to that of Plan A. Other measures such as breaking resistor or construction of an intermediate substation between Billings and Great Falls could be used instead of increasing the series capacitor compensation. An alternative to these measures is reducing reliability slightly by temporarily dropping Colstrip generation when a sufficiently serious fault or line tripping occurs that would otherwise cause instability. Some plants in the WSCC area and elsewhere are using or have in the past used automatic generator dropping in conjunction with loss of a critical line in order to maintain stability of the rest of the plant and system. If generator tripping were used, it might be needed for only a few years because growth of the load in Montana would shortly make such dropping unnecessary. The applicants could be financially penalized by the WSCC power pool for generation dropping due to subsequent reduction in availability of Colstrip generation. The cost of this penalty would be needed to properly evaluate this alternative. Plan B is definitely feasible.

Plan C has the same length of 500 KV route as Plan B. The applicants might have to increase series compensation to 55% to make Plan C's stability comparable to Plan A. The discussion under Plan B also applies here. Thus, Plan C is also feasible.

Plan D has 1,090 circuit miles of 500 KV transmission (23% more than Plan A), has one additional 500 KV substation, and would require much more in the way of auxiliary equipment or other measures to make its stability comparable to Plan A. This stability problem would exist in the initial period, beginning in 1979. In later years, Plan D has advantages in the way the load in Montana is supplied. It could be more feasible, but because of its higher cost and the additional measures needed to make it workable, it is a much less attractive plan to pursue.

The applicants have the responsibility to determine the method used to make each of these plans acceptable to their needs. There are sufficient ways this can be done so that Plans A, B and C are considered feasible and acceptable from an engineering standpoint. As mentioned earlier, comparison of the cultural and natural environmental impacts of these routes is presented in Section 6.

CHAPTER FOUR Transmission Line Design Criteria and Specification Analysis and Impact Magnitude

4.1. Design Criteria

The selection of twin 500 KV A.C. overhead transmission lines proposed by the applicants was based on the following criteria:

1) The coastal area of the WSCC grid system (Washington, Oregon, California, and Arizona) which comprises more than half of the total system is interconnected with 500 KV transmission lines. If the remaining portion, (Montana, Wyoming, Colorado and others) is connected with 500 KV lines, the loop will be completed. Therefore, the Colstrip to Hot Springs 500 KV line would be essential to complete the WSCC loop.

2) There are no lines above 230 KV in Montana, with the exception of one line going west from Hot Springs, owned by BPA. To transmit 1300 MW of power a distance of 440 miles, two 230 KV lines are not adequate. The next adequate voltage level for the Colstrip-Hot Springs line is 500 KV.

3) When only one transmission line serves an area and a fault or forced outage occurs on that line, generation will be reduced, and customers served by the line may suffer a temporary power shortage. To provide reliable service, a second line, ideally (in terms of system reliability) in a separate corridor, is required. For this project it has been proposed that two separate 500 KV lines, each on its own tower system, be built in the same corridor.

4) There are technical and economic reasons for routing the two lines adjacent to each other:

a) One intermediate substation (which contains a transformer, compensation equipment, circuit breakers, and other equipment discussed in Section 3.4.2.) every 150 miles can fulfill compensations for both lines. This would reduce the cost of the project.

b) The two lines can be connected in six independent segments as shown in Figure 4-1, with interline connections at the two proposed substations. In the event of a fault on any one segment of the line, the full load will be carried by the five remaining segments; the system will not be disturbed, and generation will not be reduced.

5) Information on the land use requirements of high voltage lines is shown in Table 4-1.

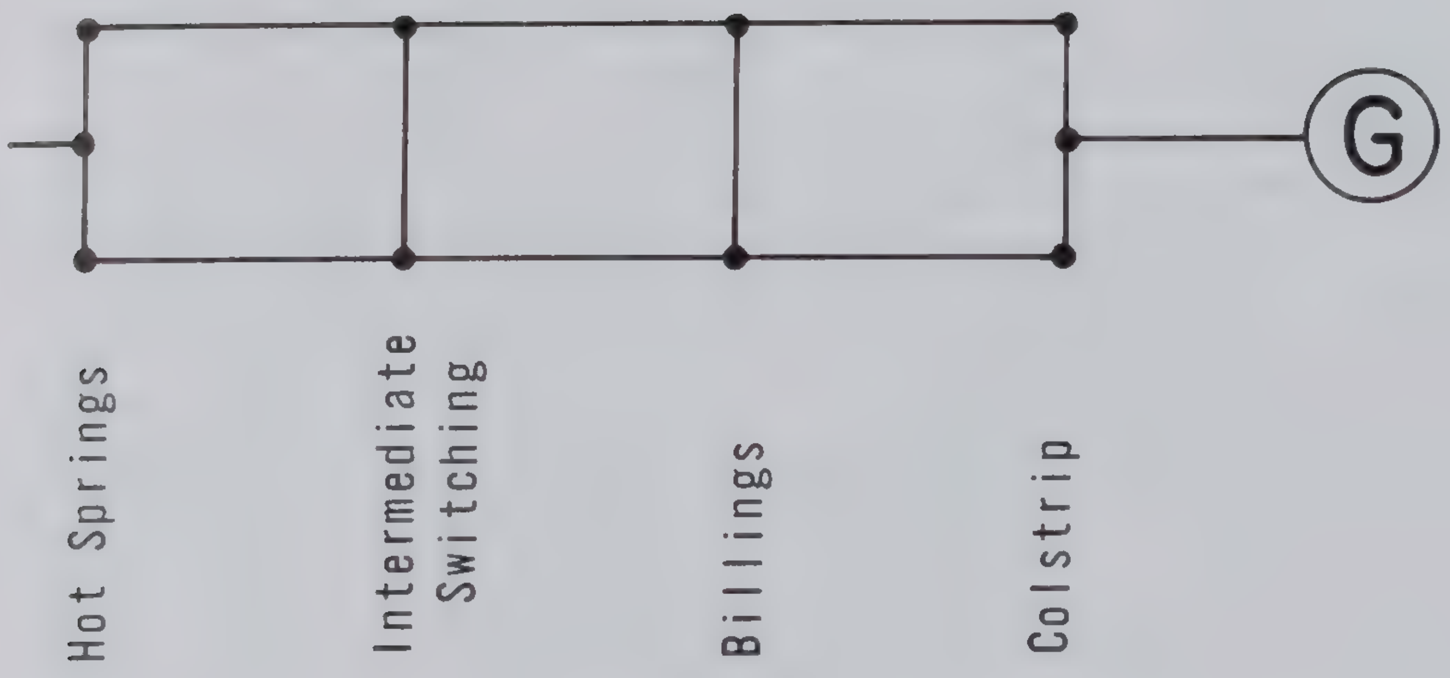
TABLE 4-1

LAND UTILIZATION WITH INCREASING VOLTAGES[1]

KV	Minimum Right-of-Way (feet)	Power Transfer With Least Expense in MW (SIL-MW)	Right-of-Way Land Per Mile in Acres	MW Per Acre	Number of 230 KV Circuits Needed for Equivalent Power Transfer
230	75	150	9.09	16.5	1
345	90	400	10.91	36.7	4
500	125	900	15.15	59.4	6
765	160	2100	19.39	108.3	14
1100	180	4100	21.81	188.0	27
1300	200	5900	24.24	243.4	39
1500	220	8100	26.66	303.8	54

---

[1] All lines are single circuit, without compensation equipment, and utilizing "V" type conduction configuration



TWO-LINE INTERMEDIATE CONNECTION

FIGURE 4-1

4.2. Physical Characteristics of the Proposed System

4.2.1. Right-of-Way and Conductors

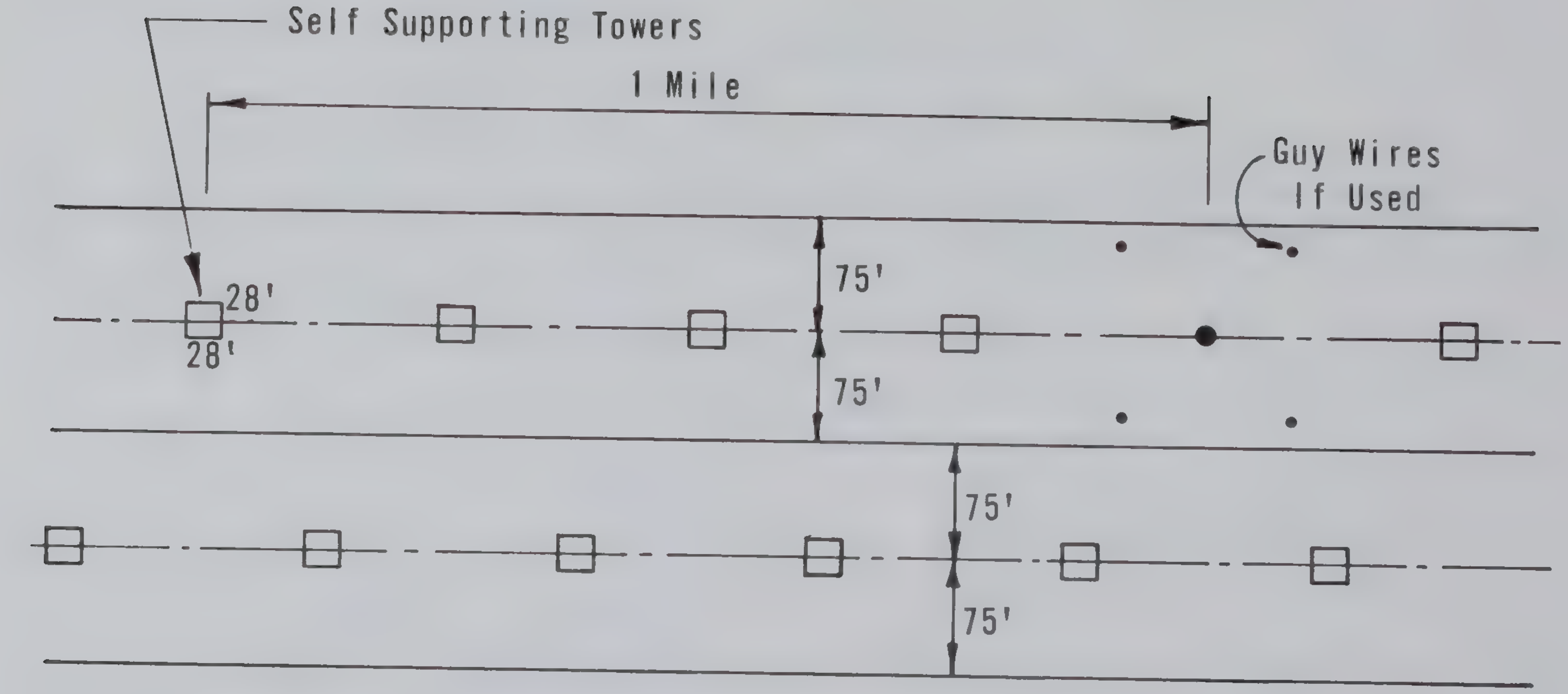
4.2.1.1. Right-of-Way Width

The proposed width of the right-of-way is 300' for both lines, with towers of the two lines placed alternately as safeguards for reliability within the corridor, averaging four to five towers per line per mile (Figure 4-2).

The land would be acquired by easement (see Volume 2, Chapter 2). Landowners would be free to use land under the lines, but precautions would be necessary. Petrol fueling under conductors or piling up dry grass beneath them is not advisable. Water from sprinkler systems operated near high-voltage lines should not touch the conductor because an electric charge could follow the water back to the sprinkler, damage it, and severely shock anyone in contact with it. (For further discussion of impacts on land use, see Section 6.2.1.)

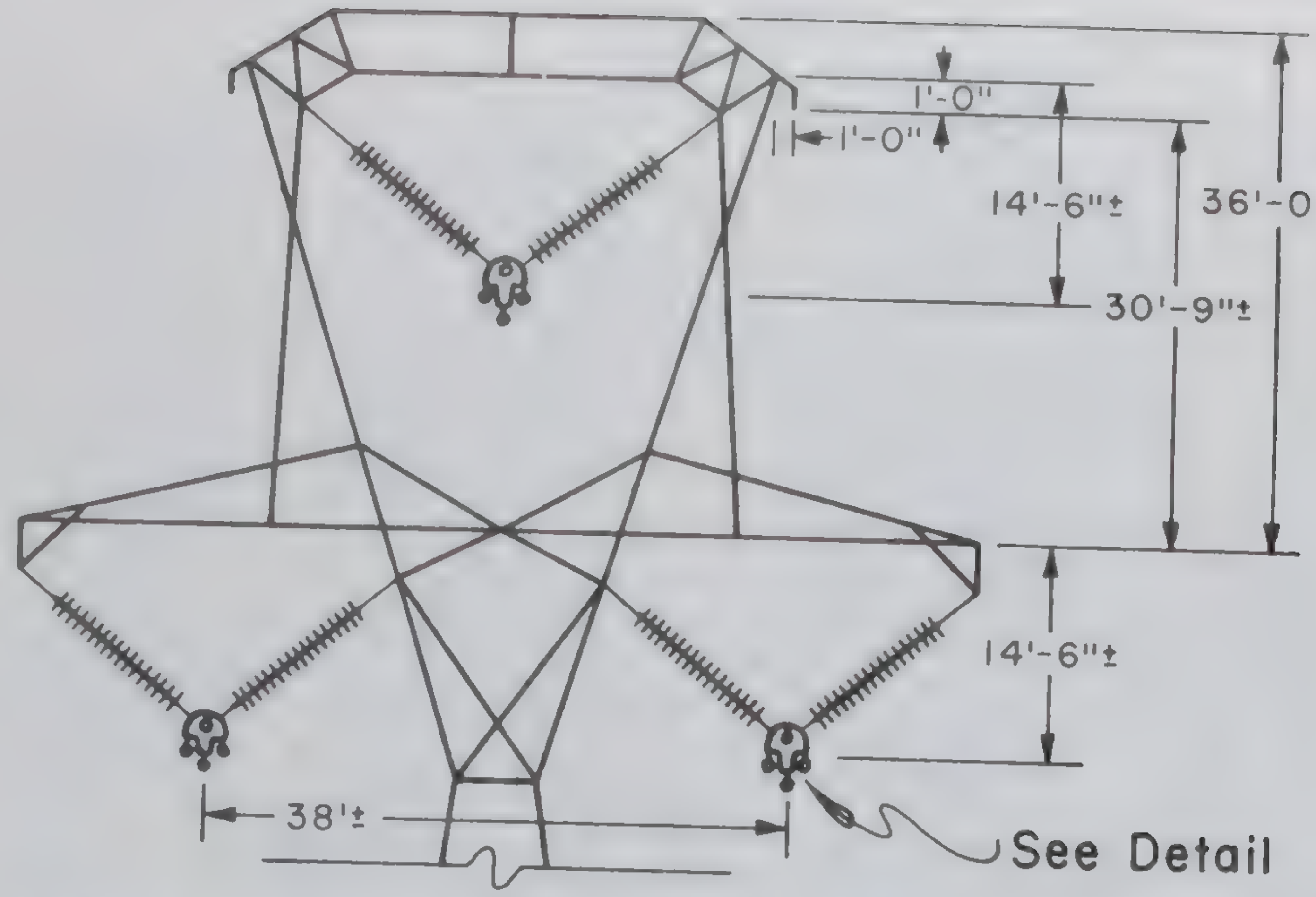
4.2.1.2. Conductors

Twelve conductors are proposed to be carried by each of the two tower systems. Four conductors, spaced 18" apart would make up each of the three phases, phases would be spaced 38' apart (see Figure 4-3). The diameter of the conductors (795 MCM ACSR Mallard) would be 1.140" (MPC 1974), and the combined weight would be approximately 33 tons per mile on the average. Minimum ground clearance of the conductors would be 37'.

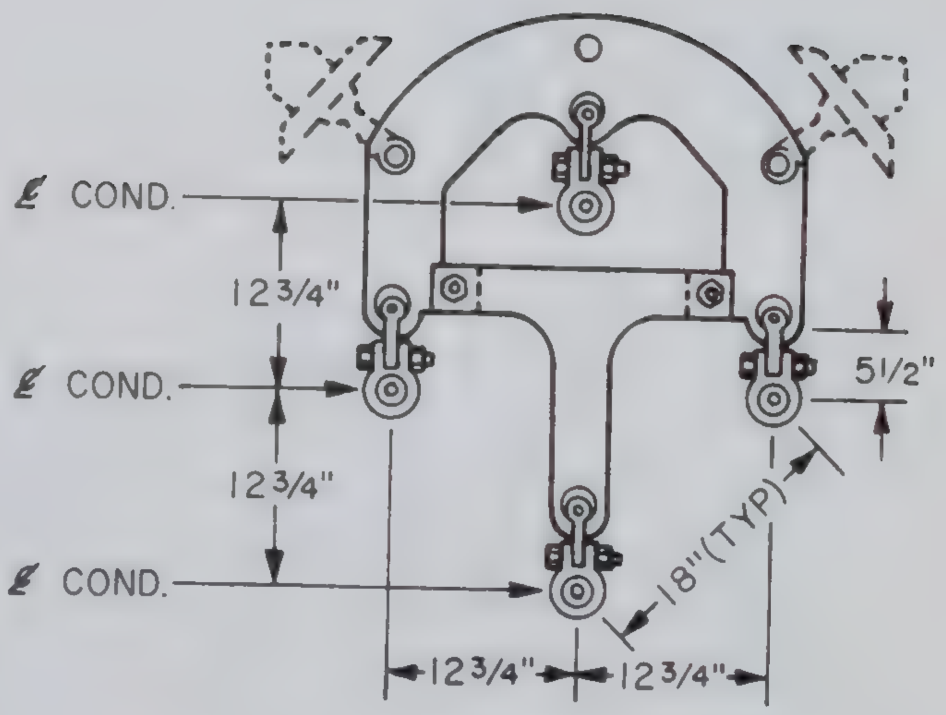


ALTERNATE LOCATION OF TOWERS

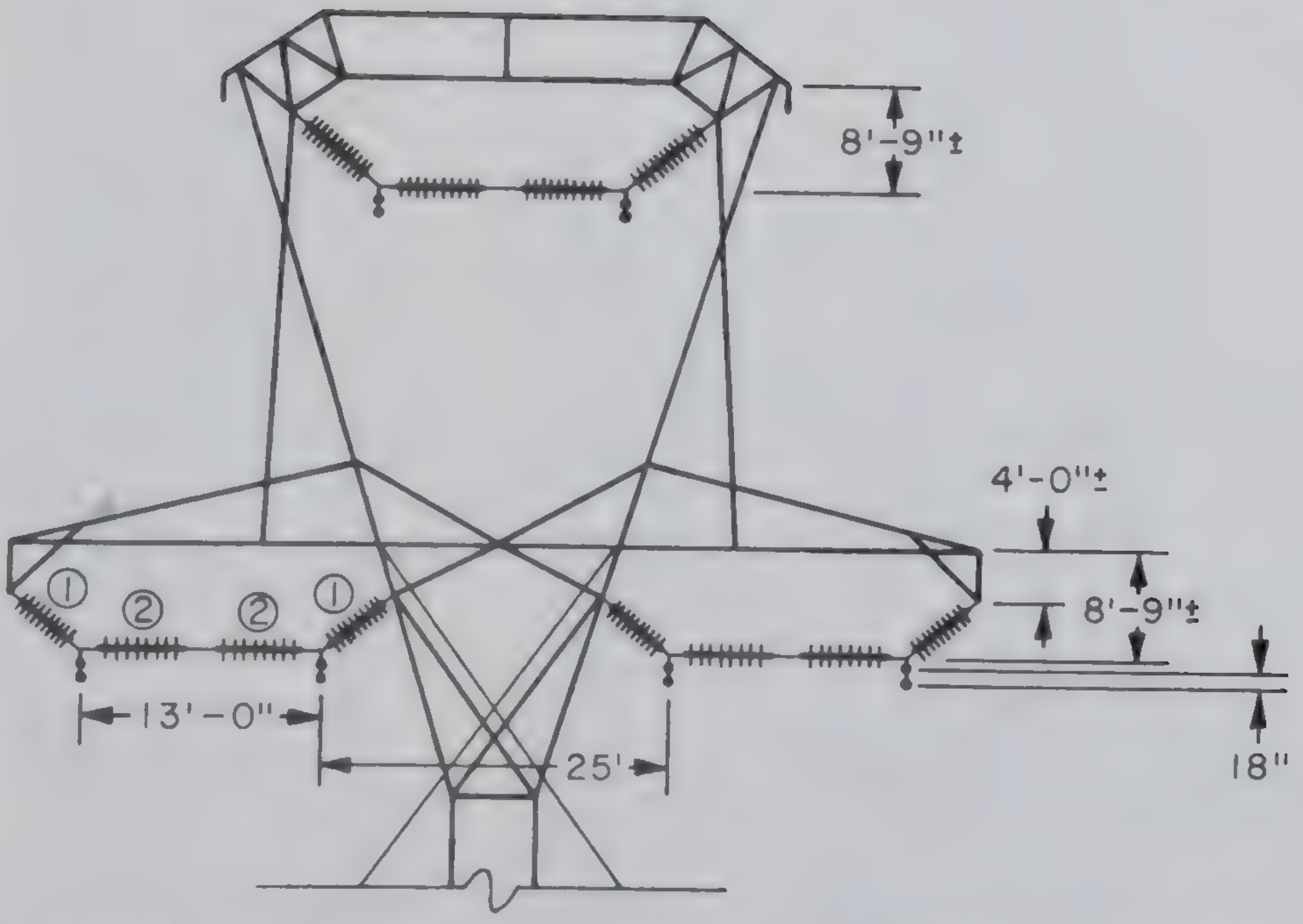
FIGURE 4-2



500 KV SINGLE CIRCUIT ARRANGEMENT



DETAIL



① 14 Insulator rings

② 11 Insulator rings

230 KV DOUBLE CIRCUIT ARRANGEMENT

Same tower top as 500 KV tower (Proposed for one line from Colstrip to Broadview and convertible from two 230 KV circuits to one 500 KV circuit.)

Figure 4-3 (Westinghouse 1973)

4.2.2. Tower Body and Foundation

The applicants have proposed two tower structures, both of which would be used on the proposed line.

Self-supporting tower (Figure 4-4): This structure has a 28' x 28' base, is 145' high, and of a steel lattice construction. The average weight of the tower would be approximately 10 tons. At river crossings, or other areas where more strength is required, these self-supporting towers would be used. The foundation would be 20' to 25' deep, depending on the terrain.

Guyed tower (Figure 4-5): This structure is held in place by four guy wires anchored 66' to 70' away from the base of the tower. Because of the greater total width at the ground, guyed towers would in some areas cause more interference with the existing land use than would self-supporting towers. The average weight of the towers would be 8 tons.

The number of towers per mile would range from four to six. There would be 25-25 insulators ($10\frac{1}{2}$" in diameter) per phase on each tower (see Figure 4-3) (Westinghouse 1973).

4.2.3. Substations

Little is known at this time about the construction or specific locations of the proposed substations. One would be located near Billings. Another would be needed between Billings and Hot Springs. This intermediate substation would not include a transformer until some time in the future when tapping of the lines would be required (Westinghouse 1973). Until that time it would serve as a switchyard. There is a 500 KV substation in existence at Hot Springs, owned by BPA, which can be expanded as required to accomodate the proposed line. The Hot Springs substation is presently the only such substation in Montana.

4.3. Construction and Maintenance

4.3.1. General Description

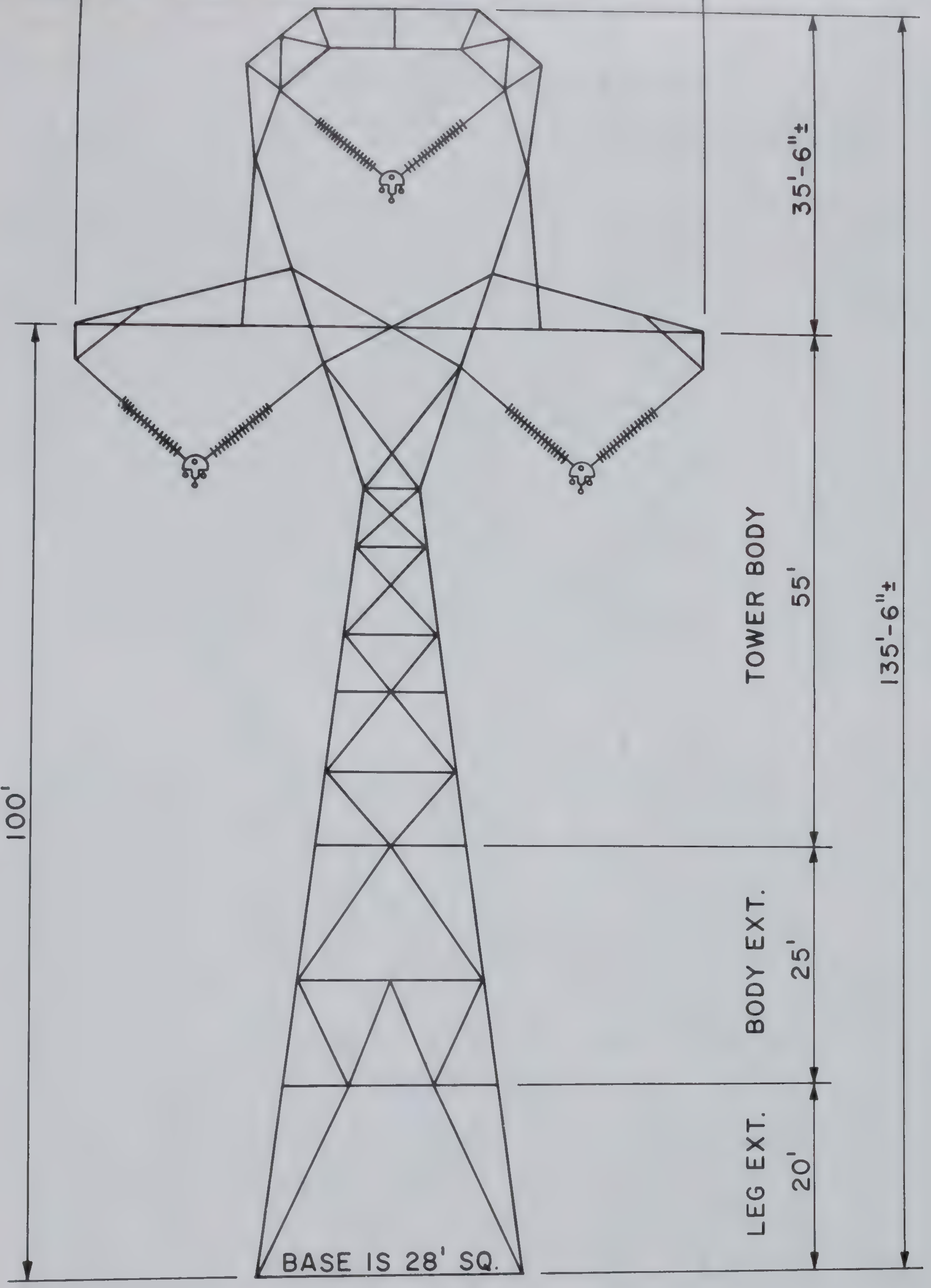
4.3.1.1. Construction

Construction can be categorized into the major areas of construction survey and staking, clearing, road construction, tower construction and erection, stringing of conductors, and clean up and restoration.

A. Survey and Staking

This is required for all rights-of-way, tower sites, roads, substations, and other engineered or controlled facilities associated with the transmission line project such as communication sites, staging areas, helicopter landing areas, wire stringing sites, and others.

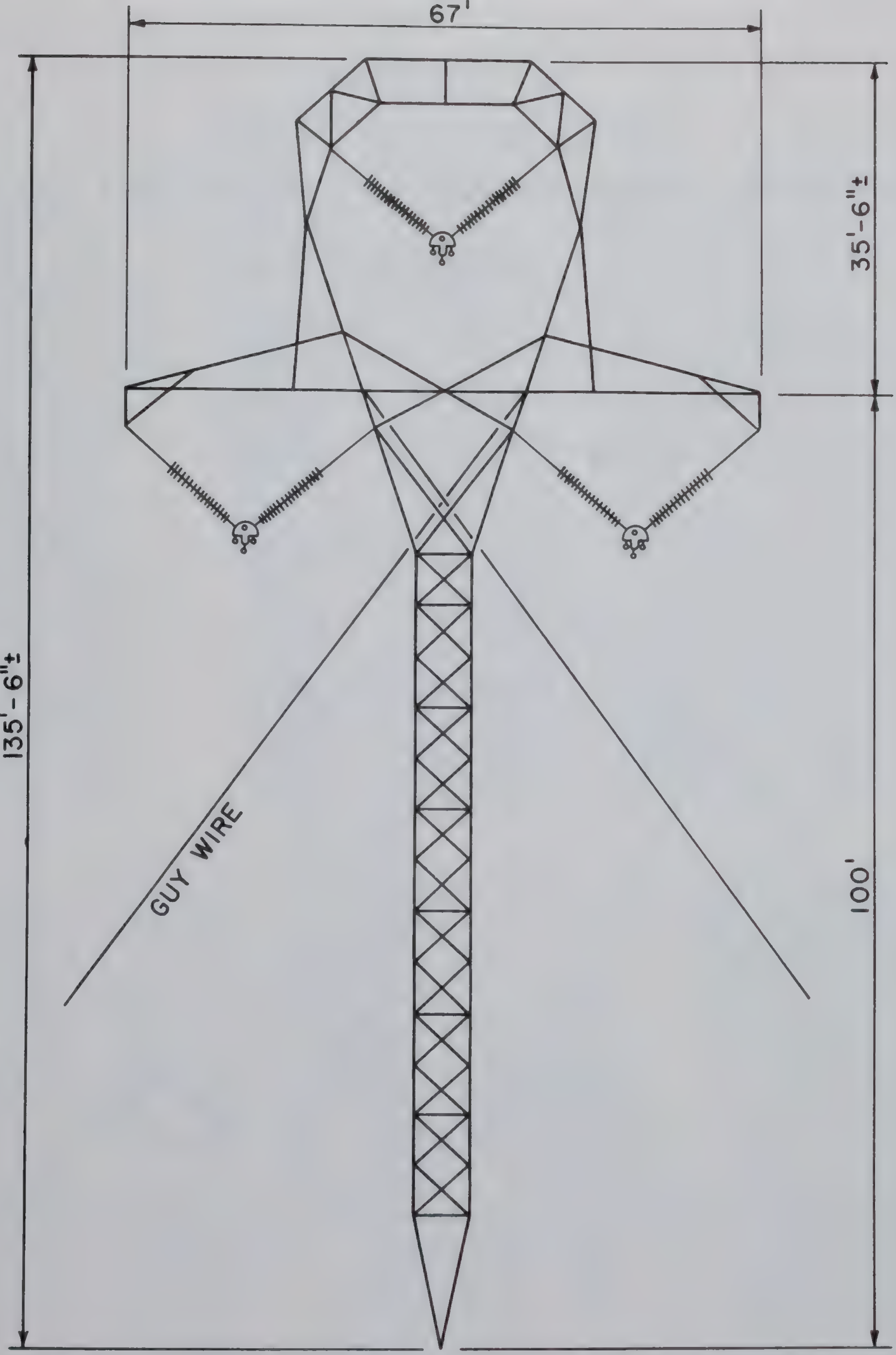
The surveyors and their euipment are the first on the scene. Construction survey is usually more detailed and intensive than design survey. Some clearing and much mobility along the



500 KV SINGLE CIRCUIT TOWER – SELF SUPPORTED
DELTA CONFIGURATION

(Westinghouse, 1973)

Figure 4-4



500 KV SINGLE CIRCUIT TOWER – GUYED DELTA CONFIGURATION

(Westinghouse, 1973)

Fig 4-

right-of-way is required. The crews are small, about three or four people.

Other engineering data may be necessary such as tower foundation investigation. This type activity may be concurrent with the construction survey phase.

B. Clearing

This includes all operations needed to open up the sites described above to enable construction and future operation of the planned facilities. Clearing consists primarily of vegetative removal or modification such as crushing. Man-made objects such as buildings or fences may require modification, moving, or demolishing. Sometimes other natural barriers are cleared such as rock outcroppings.

Equipment ranges from hand tools to large bulldozers. Crew sizes vary with equipment used, vegetative density, and complexity of the clearing operation. The number of workers may be from three or four 24 or 30. Once the vegetative material is removed, it must be disposed of or moved away from construction activities. Disposal may be by burning, burying, chipping, or movement to a remote disposal site. Sometimes this material is piled and later scattered in open areas after construction. Marketable timber is usually sold. The proposed transmission line right-of-way is a single 300-foot wide path for both lines. If the total 300 feet were cleared, the area cleared would be slightly over 36 acres per line mile.

Selective clearing outside normal rights-of-way may be needed to remove danger trees such as large snags or other tall trees which could fall onto conductors or towers.

Generally complete clearing of line right-of-way even at tower sites is not done.

Tower sites require space for assembly and erection of towers up to 150 feet high. The tower tops are about 65 feet wide. Flat bed trucks and large cranes with booms over 150 feet are needed at tower sites so adequate clearing is needed for this type of equipment. If the 300-foot right-of-way is fully cleared, there should be adequate space within this area for tower sites, if not, tower site clearing is at least 150-foot square or about a half acre.

The base of the proposed four legged self-supporting tower is 26-foot square. The guyed tower has one main tower leg supported by four guy wires on a 118-foot square (see Figures 4-4 and 4-5). The average span is 1,300 feet between towers or about four towers per mile. Span lengths can be as long as 2,500 feet or down to 800 feet depending on terrain or other conditions such as highways, railroads, angles, and dead-ends. Tower sites are usually cleared more completely than line right-of-way, especially under the tower and where cranes are located.

If counterpoise installation is needed because the earth ground resistance of the tower footings is too high for proper electrical grounding of the tower, complete clearing is required for the burial of ground wires either radiating from tower footings or between one or more towers. The burial can be by hand trenching, plowing in, or machine trenching.

Substations are completely cleared and are usually built in presently open areas. They can occupy many acres initially or ultimately as substation equipment expands.

Communication sites require clearing for microwave towers, small buildings, access roads, powerlines, and microwave paths. This is usually complete clearing of selected areas. These sites are usually away from the transmission line on high mountain peaks or ridges.

Other areas requiring clearing are reel sites for conductor stringing, staging or material storage areas, concrete batch plant sites, borrow areas for gravel or fill material, heliports, and possibly camp sites. Such clearings are usually complete clearing of sites ranging from fractions of an acre to many acres.

Road clearing requires complete clearing of paths from 25 to 100 feet wide or more depending on road type, use, and terrain. Normally minimal road clearing is five feet from the toe of the fill to 10 feet from the top of the cut.

C. Road Construction

Permanent existing roads may require widening, additional gravel, more drainage, or other reconstruction because of the line project. New permanent roads may be needed. Temporary roads are usually required for line construction.

Equipment and workmen are those normally used for rural road construction ranging from hand tools to bulldozers, drag lines, dump trucks, graders, and possibly large gravel crushing equipment. Total road construction crews may range into the 20's in number. Many of the same workmen and equipment used for clearing can also be used for construction. Bonneville Power Administration (BPA) estimates that approximately 1.0 to 1.5 linear miles of access road could be required per mile of transmission line depending on topography (BPA 1974).

D. Tower Construction and Erection

This includes tower component assembly, tower assembly, installation of footings and guys, tower erection, and counterpoise installation (tower grounding).

After tower sites are cleared, excavation for footings is done. Sometimes blasting is required. Some site leveling with a cat may be required for the tower and the erection crane. Excavation equipment may include backhoes, dump trucks, power augers, wagon drills, bulldozers, compressors, and blasting equipment. Augers and wagon drills are mounted on large trucks such as 5-ton 6 x 6's. Crews range from a few to a dozen and may include those employed in other construction stages.

Footing forms are installed and footings are placed with concrete hauled in conventional concrete trucks such as 9-yard units. The concrete comes from batch plants or ready mix plants which must be near enough for proper concrete quality. Batching can be done on the site by hauling in the component materials but is less efficient.

Footing and concrete work requires four to six men at the tower site and driving trucks.

Other men and equipment are needed at the batch plant to operate the plant and haul in sand, gravel, cement, and water. Materials are stockpiled at the batch plant and equipment there consists of front end loaders, cement transports, tank trucks, and dump trucks as well as the plant itself.

Tower components may be sub-assembled in staging or material areas or at the tower site. The sub-assemblies are bolted together at the tower site to complete the tower. Next the tower is lifted into place by a large crane and bolted on to the footings. Guys on guyed towers are attached before being released from the crane. In addition to cranes, tower erection equipment includes bulldozers for leveling crane sites, rigging trucks, tagging trucks, and miscellaneous vehicles such as pickups. Crew size may range up to a dozen or more and the workmen are usually highly specialized. If the earth ground resistance of the tower is not low enough, counterpoise or supplementary grounding is installed. This consists of bare copper wire buried and ground rods driven either diagonally from each tower leg or between adjacent towers. A trencher or vibratory plow can be used. In rocky ground, ripping with a bulldozer may be necessary. Three or four workmen can complete this work.

E. Conductors Stringing

Insulator strings are installed on the towers, conductors are pulled in from wire reel sites, splices are made, and final tensioning and connections of the conductors completed.

Wire pulling sites are required approximately every three miles along the line for wire trailers, pullers, tensioners, and associated equipment. These must be set up in line with the towers.

Guard structures are built over highways, railroads, powerlines, fences, and other barriers on the tramsmission path to prevent mutual damage and interference. Insulators, associated electrical hardware and stringing sheaves are installed on the tower arms.

Equipment and crews for erecting guard structures include power auger trucks, pole trailers, and medium sized vehicles. Crews are from three to four linemen. Insulator crews are also small sized and their equipment consists of hand tools and line trucks.

Next, socklines are pulled into the stringing sheaves. The socklines pull the conductor or static line into place. Socklines are pulled from the ground by tractors or from the air by helicopters. Conductors are pulled and tensioned using the powered equipment at the pulling sites.

Finally conductors are spliced, given their final tensioning or sagging, connected to the insulators or for the static lines, directly to the towers, and conductor spacers installed if required.

As soon as substations, switches, and all needed electrical equipment are installed along the lines and at the terminals, the lines can be energized.

Stringing crews require the most manpower.

F. Clean Up and Restoration

Clean up is a part of each construction phase, but final clean up and restoration or rehabilitation is whatever construction is needed to restore the various sites and rights-of-way to as nearly the original conditions as possible.

All debris, materials, and unneeded equipment is removed.

Final slash processing is completed such as scattering over open areas. Soil is replaced where severely disturbed on roads, tower sites, borrow pits, batch plant sites, and wherever else necessary.

Seeding or planting is carried out where needed. Erosion protection is constructed. Fertilizer and mulch are used if needed.

Temporary roads are obliterated and closed with barriers and signs.

Final fence, gate, and cattleguard adjustments or repairs are made.

Permanent roads are brought up to maintainable standards and conditions.

Crew and equipment are similar in makeup and size to those used in clearing and excavation.

4.3.1.2. Maintenance

Maintenance includes all functions needed to keep the lines and associated facilities in operation throughout their lifetime. Some maintenance, such as road maintenance, is required during and after construction of the lines. Other maintenance includes line patrol or inspection, vegetative management, structural and electrical maintenance. These operations are carried out both on a planned and emergency basis.

4.4. Electrical Characteristics of the Proposed System

The proposed twin 500 KV overhead A.C. transmission lines have the following technical characteristics:

Conductor:

795 MCM ACSR
diameter = 1.140"
30 aluminum strands
19 steel strands
R = .125 ohms/mile at 50°C
X_L = .4890 ohms/mile
X_C = .1181 megaohms/mile
SIL (Surge Impedance Level) = 980 MVA

The power-carrying capacity of each line would vary accordint to load conditions, but the load-carrying capacity for each line is about 1500 MVA or 1400 MW (assuming 440 miles of compensated line. Depending on series compensation, power-carrying capacity would vary.).

4.4.1. Corona Effect

The corona phenomenon is mainly associated with high-voltage overhead transmission. As discussed in Section 3.1., air acts as an insulating agent around the conductors in overhead transmission systems. When A.C. current is carried in a conductor, it will induce an electromagnetic field in the air surrounding that conductor (see Figure 4-6). The intensity of that electromagnetic field (E) or voltage gradient on the surface of the conductor is expressed in units of KVp/cm (peak kilovolt per centimeter). When E exceeds the breakdown strength of air, (which is about 29.6 KVp/cm or 21 KV_{rms}/cm) the air in the vicinity of the conductor is no longer an effective insulator. This value of E is called the critical voltage gradient. This breakdown strength is dependent on such conditions as air pressure, presence of water vapor, type of voltage, and condition of the conductor surface. The electromagnetic field, caused by a discharge of electrical energy (which contributes to line loss), accelerates free electrons in the surrounding air. When these electrons acquire sufficient energy, they can collide with atoms of oxygen, nitrogen, and other gases with enough force to knock electrons from those atoms, producing fresh unstable ions. This process is called ionization of air (see Figure 4-7). Most of these collisions, which occur at the surface of the conductor, are elastic collisions, much like a collision between two billiard balls: when atomic excitation occurs, the involved atom shifts to a higher energy state. Later, that atom may revert to its normal state, radiating the excess energy in the form of noise, light, or heat (Figure 4-8). This phenomenon is known as corona, defined in the IEEE Standard Dictionary (1972) as "a luminous discharge due to ionization of the air surrounding a conductor caused by a voltage gradient exceeding a certain critical value." The effects of corona discharge are discussed in the following sections.

4.4.1.1. Audible Noise

An increase in corona noise levels in the audible spectrum causes audible noise. The highest audible noise levels are induced during periods of precipitation, or after a rain while the conductors are still wet.

This noise consists of two components: a broadband "white" noise which covers the total frequency spectrum and harmonics (multiples of the fundamental $60H_z$ power line frequency). These $60H_z$ harmonics produce a humming sound, and the "white" noise is manifested as crackles or pops. Table 4-2 relates familiar noise-producers to their equivalent levels in decibels (db), the unit used to measure sound.

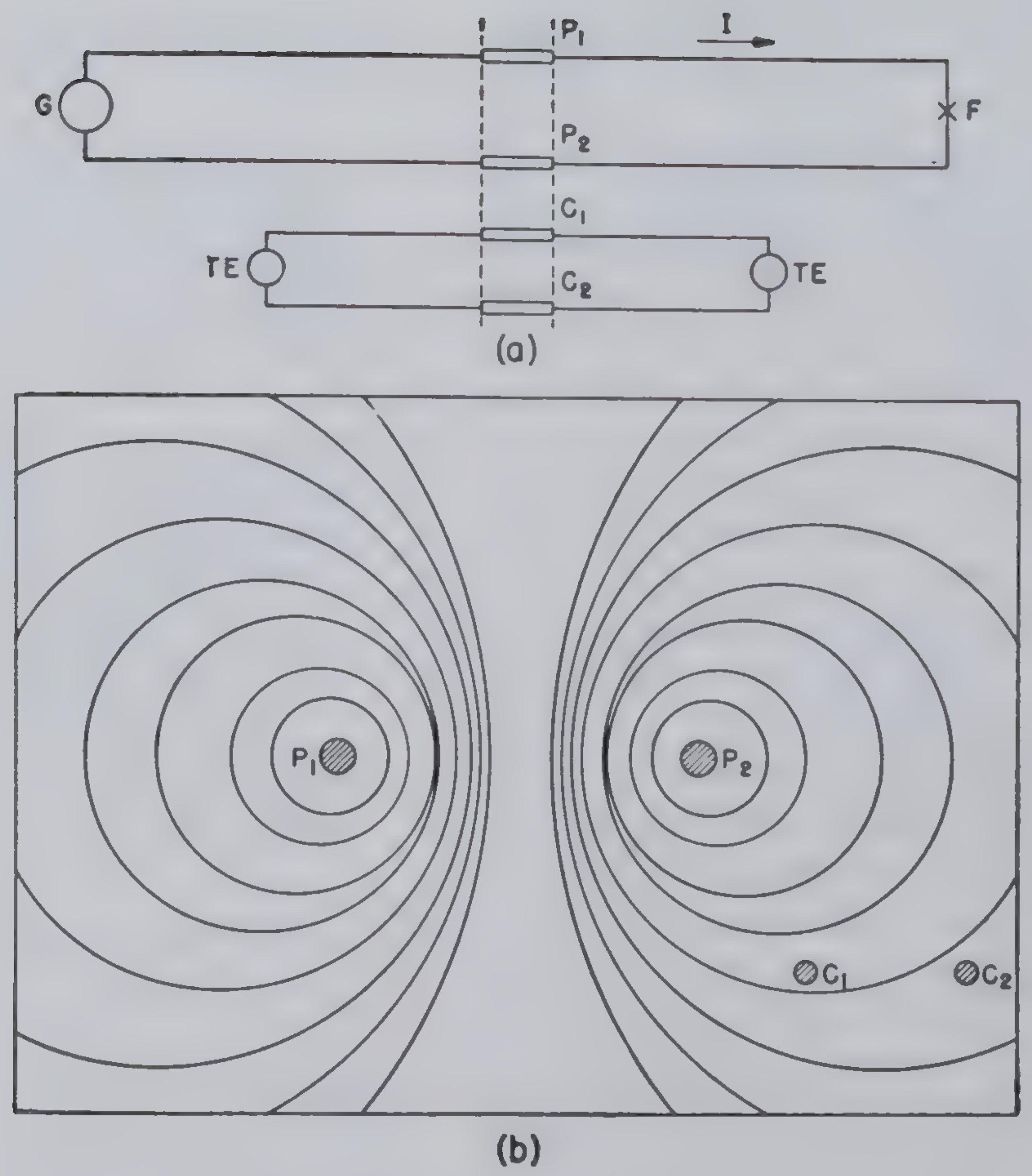
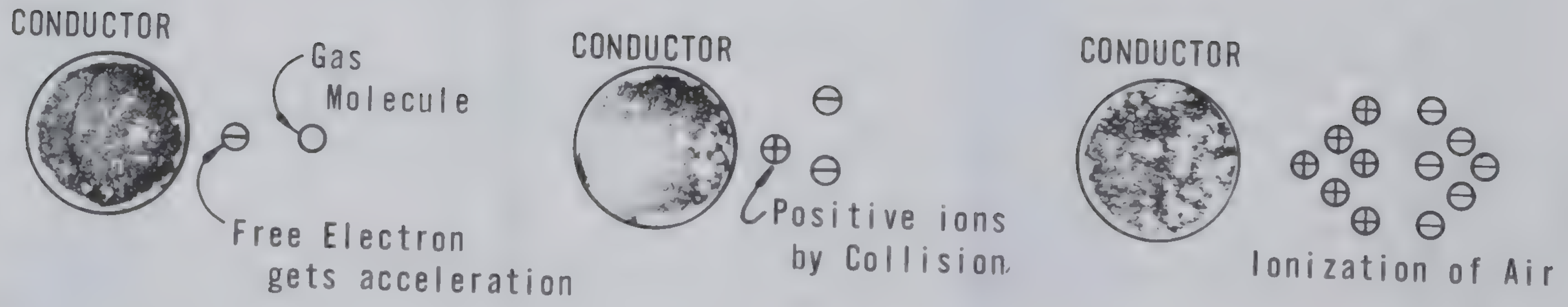


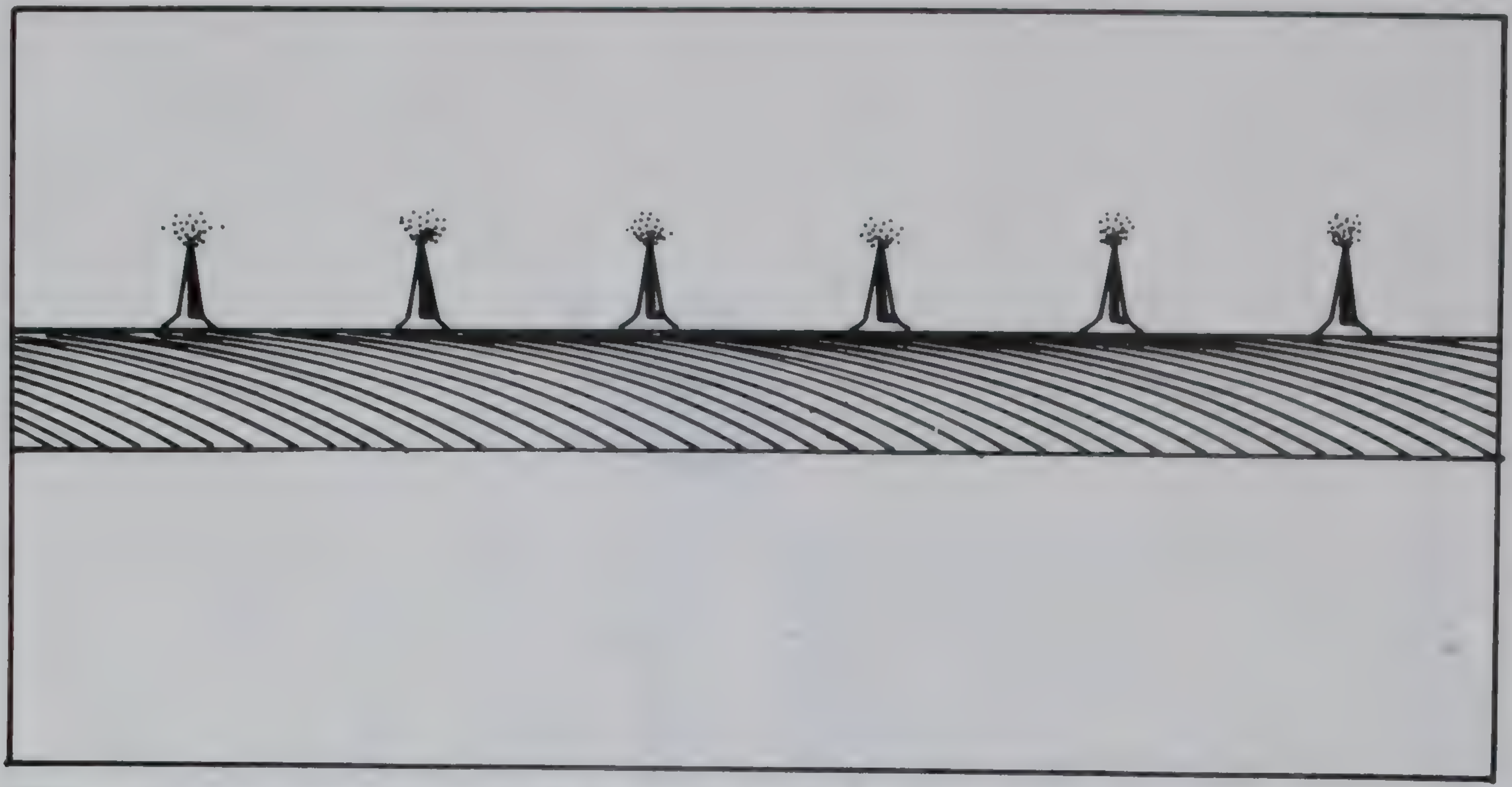
Figure 4-6: Electromagnetic Induction from a Metallic Power Circuit on a Metallic Communication Circuit
C_1 and C_2 are Communication Lines - P_1 and P_2 are Power Lines

Westinghouse, 1964

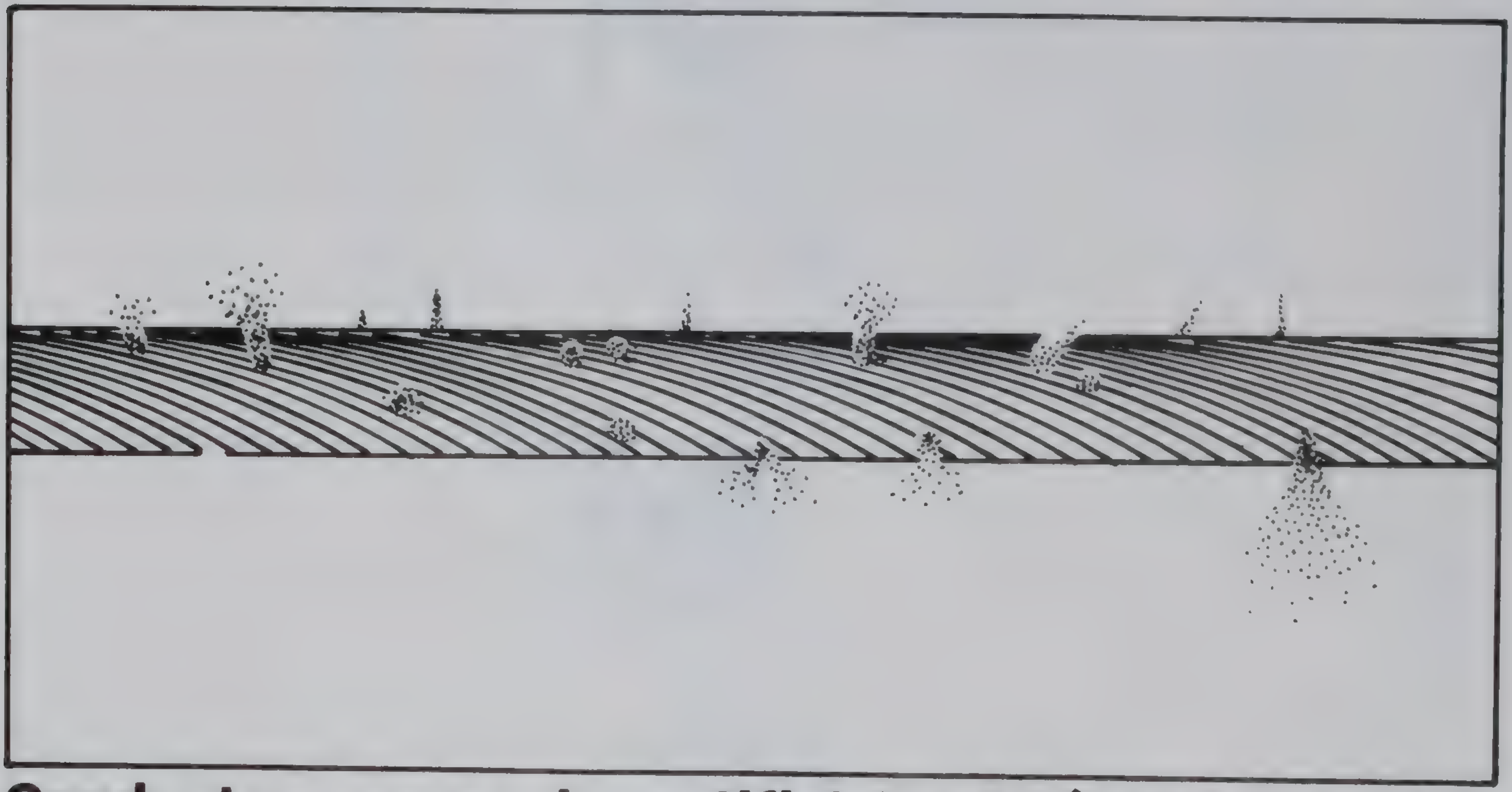


IONIZATION

FIGURE 4-7



Glow corona on sharp points on the conductor



Conductor corona in artificial rain (conductor diam. 0.75 in 1.3cm. Gradient=20.6KV/cm rms.

FIGURE 4-8 (IEEE 1971)

Table 4-2

SOURCE	NOISE LEVEL IN db's
Threshold of pain	120
Riveter	95
Front row at orchestra	90
Busy street traffic	70
Ordinary conversation	65
Quiet automobile	50
Quiet radio at home	40
Average whisper	20
Rustle of leaves	10
Threshold of hearing	0

Decibel levels known to cause annoyance are shown in Figure 4-9. Transmission line noise recorded on an oscilloscope is shown in Figure 4-10.

Since little theory has emerged concerning audible noise, noise levels for new lines are usually estimated from data on similar existing lines. Figure 4-11 predicts noise levels for lines of various ratings. Audible noise for the proposed two lines would be about 51 db., which, referring to Figure 4-9, indicates a low probability of receiving complaints.

4.4.2. Radio and Television Interference

Corona discharge covers a broadband frequency spectrum. Some of these frequencies interfere with radio-wave propagation which propagates by natural phenomena or by transmitters (see Figure 4-12).

Radio stations and television channels operate at wave frequencies assigned by the Federal Communications Commission. The area coverage of these waves depends on the transmitting power capacity of the antenna. The areas in the frequency spectrum most susceptible to interference by corona discharge are the AM radio broadcast band and video portions broadcast by television channels 2 and 6.

4.4.2.1. Radio Frequency Interference (RFI)

Each radio station has knowledge of its approximate coverage area, and whether reception within the area is good or satisfactory. This information is shown for Montana on the Radio/TV Reception Map. Standards for reception quality, established by the FCC, are found in Table 4-3.

Table 4-3

Service	Area	Minimum Signal Level	dbm
Primary	10 mile radius from antenna	1500 mv/m (millivolt)	63.5
Secondary	30-mile radius	500 mv/m	54.0

Reception quality is directly related to signal strength (mv/m) and inversely related to disturbances or noise (interference). When both quantities are measured in dbm (db = 20 log mv/m), their ratio is called the signal-to-noise

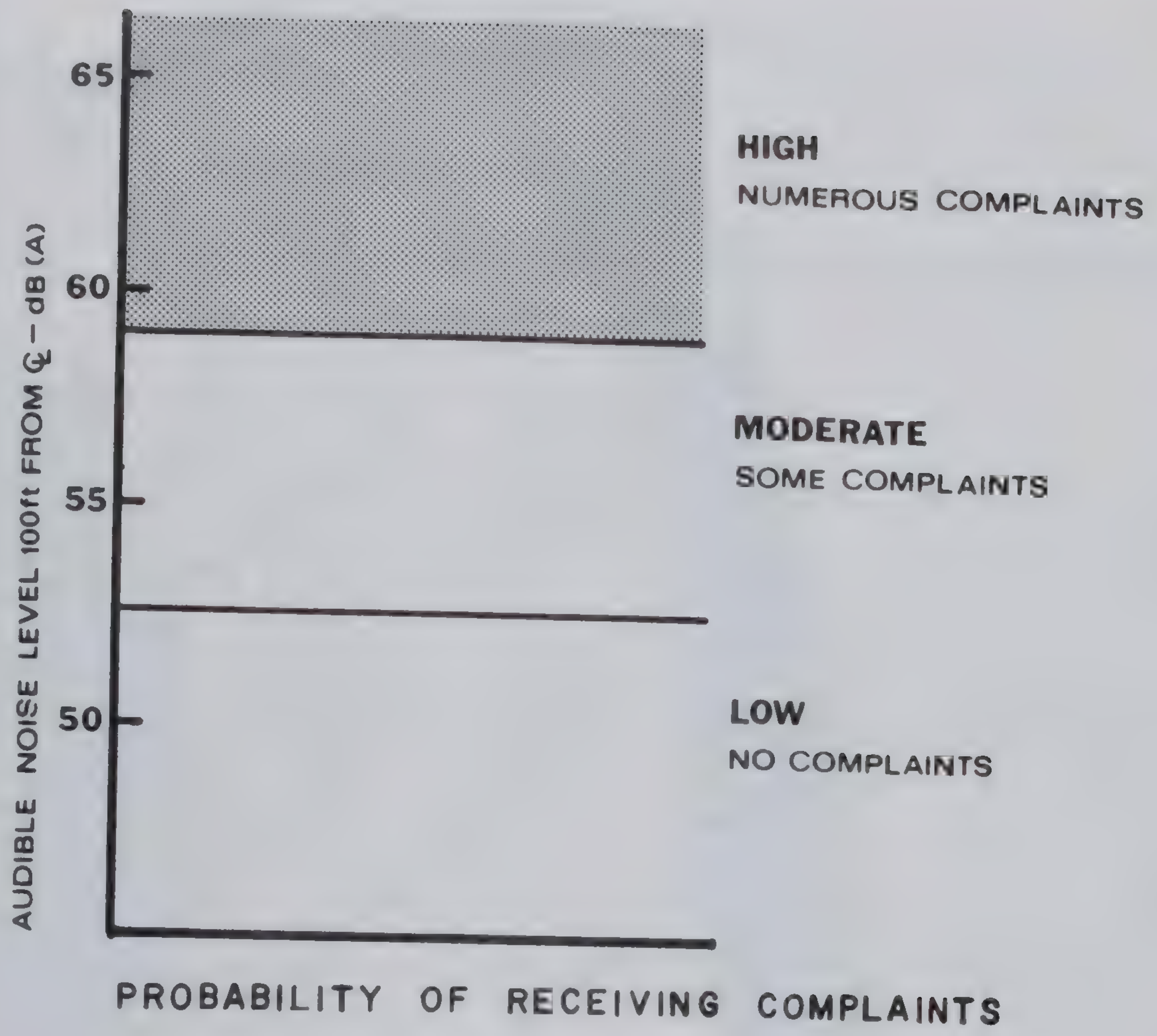
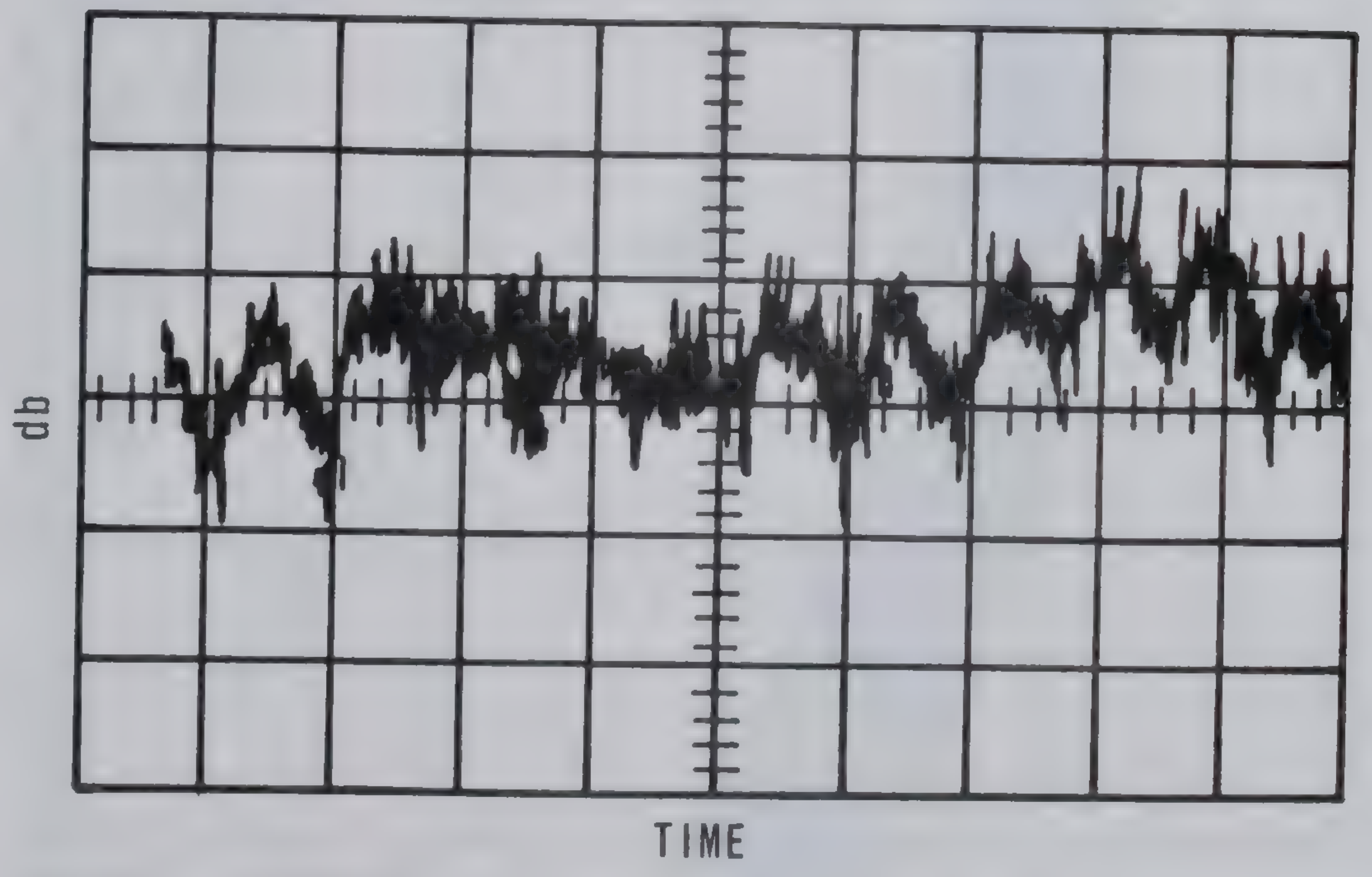


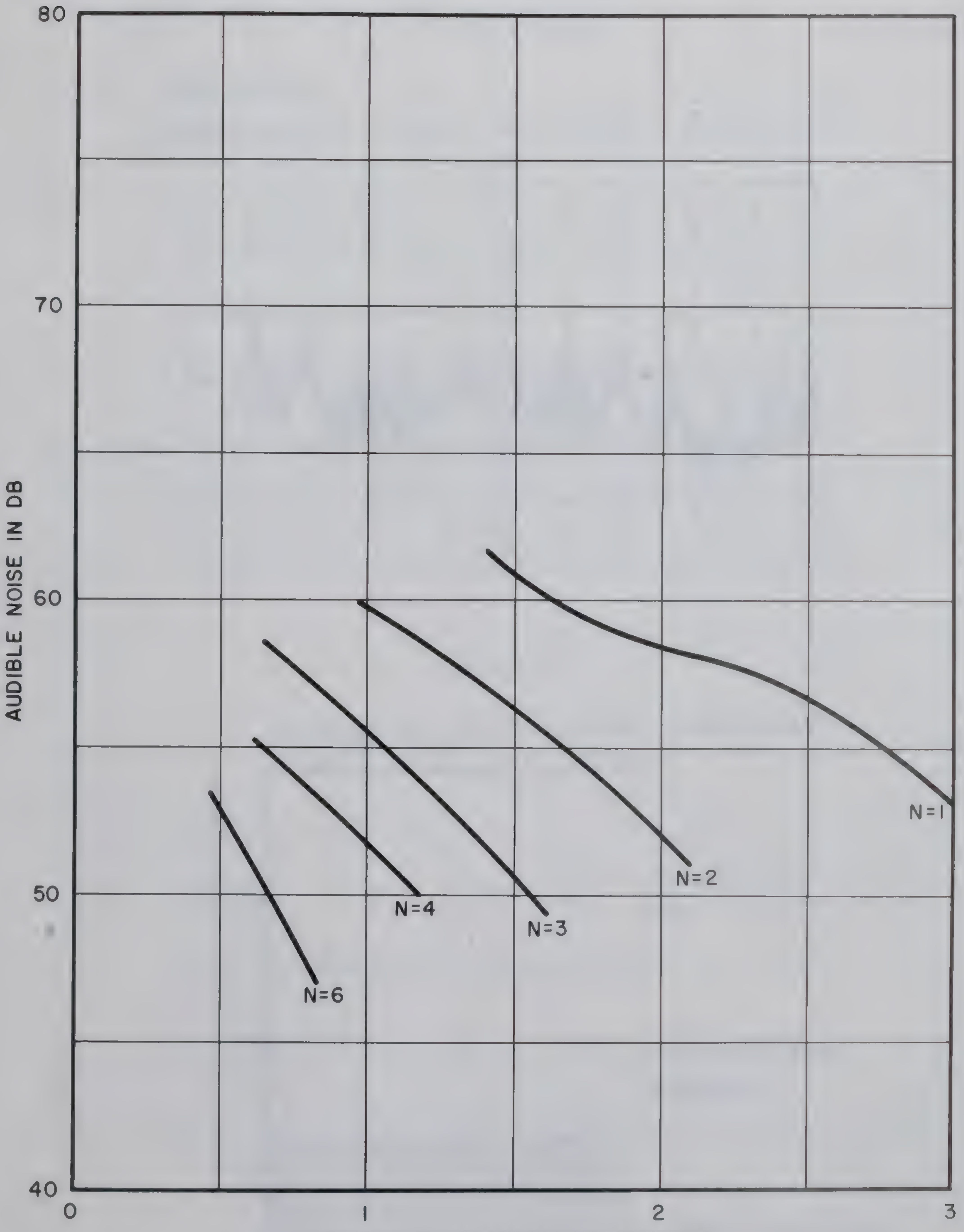
FIGURE 4-9



OSCILLOSCOPE RECORD OF AUDIBLE TRANSMISSION LINE NOISE

FIGURE 4-10

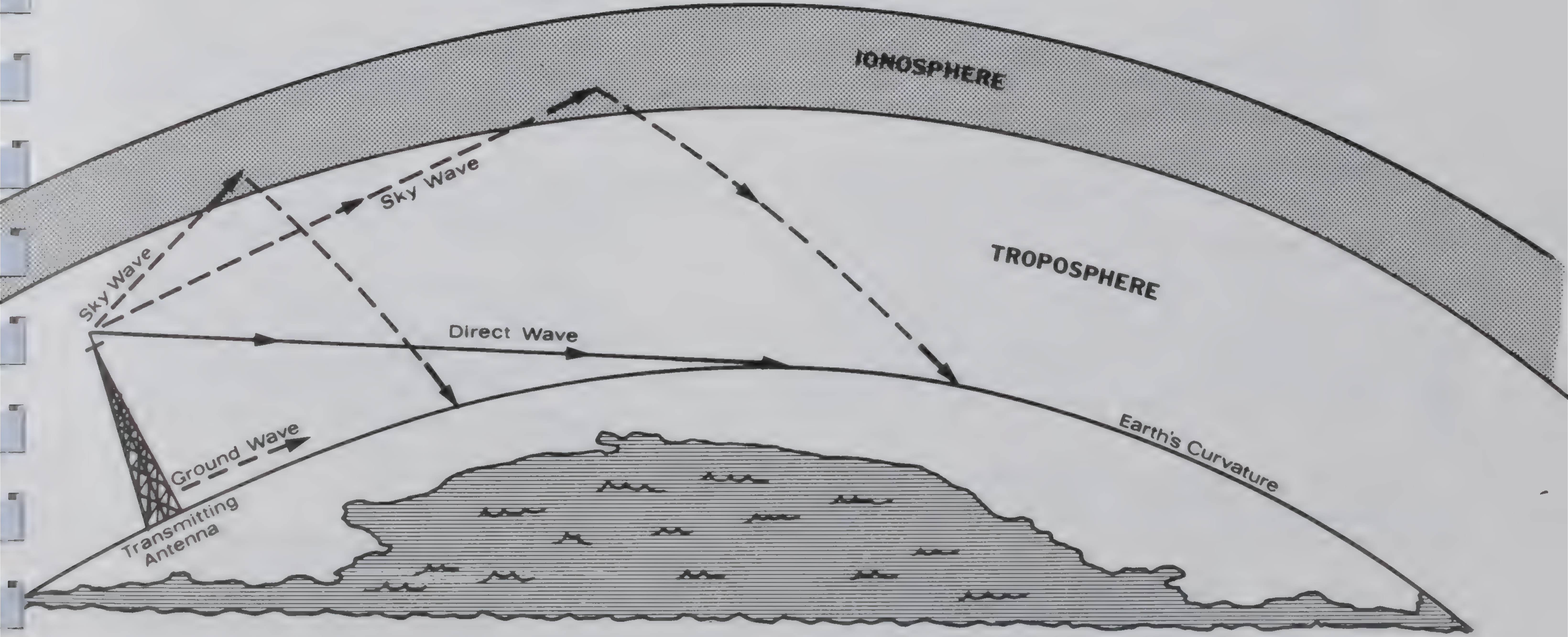
(IEEE 1971)



AN AT 100 FEET FROM OUTER PHASE OF 500 KV LINES
UNDER RAIN, BASED ON CAGE TESTS

(IEEE, 1970)

FI RE 1



Propagation of radio waves

FIGURE 4-12

ratio—SNR. Table 4-4 relates SNR to radio reception quality.

Table 4-4

Grade	Description of Reception	SNR
A	Excellent	32 db or higher
B	Good	27 db to 31 db
C	Fairly Satisfactory	22 db to 26 db
D	Speech Understandable	16 db to 21 db
E	Speech Understandable With Severe Concentration	11 db to 15 db
F	Unintelligible	10 db or less

SNR have been calculated for the proposed line (see Appendix I6). Based on those calculations, it is predicted that in normal weather, at 1000' from the line, the noise level may be as high as 24 db, and in foul weather, as high as 40 db.

The graph (4-18) is the result of four theoretical methods for noise level prediction at different distances.

Conclusion: The interference to the reception of AM radios, communication radios, citizen band radios and others is dependent upon the distance from the middle conductor. Specific predictions of RFI will involve a case-by-case study.

If twin 500 KV lines are approved, to mitigate these effects the following guidelines are suggested:

1) Locate centerline away from radio and TV transmitters and receivers.

2) If possible select structure heights to avoid direct interference with radio and TV transmission.

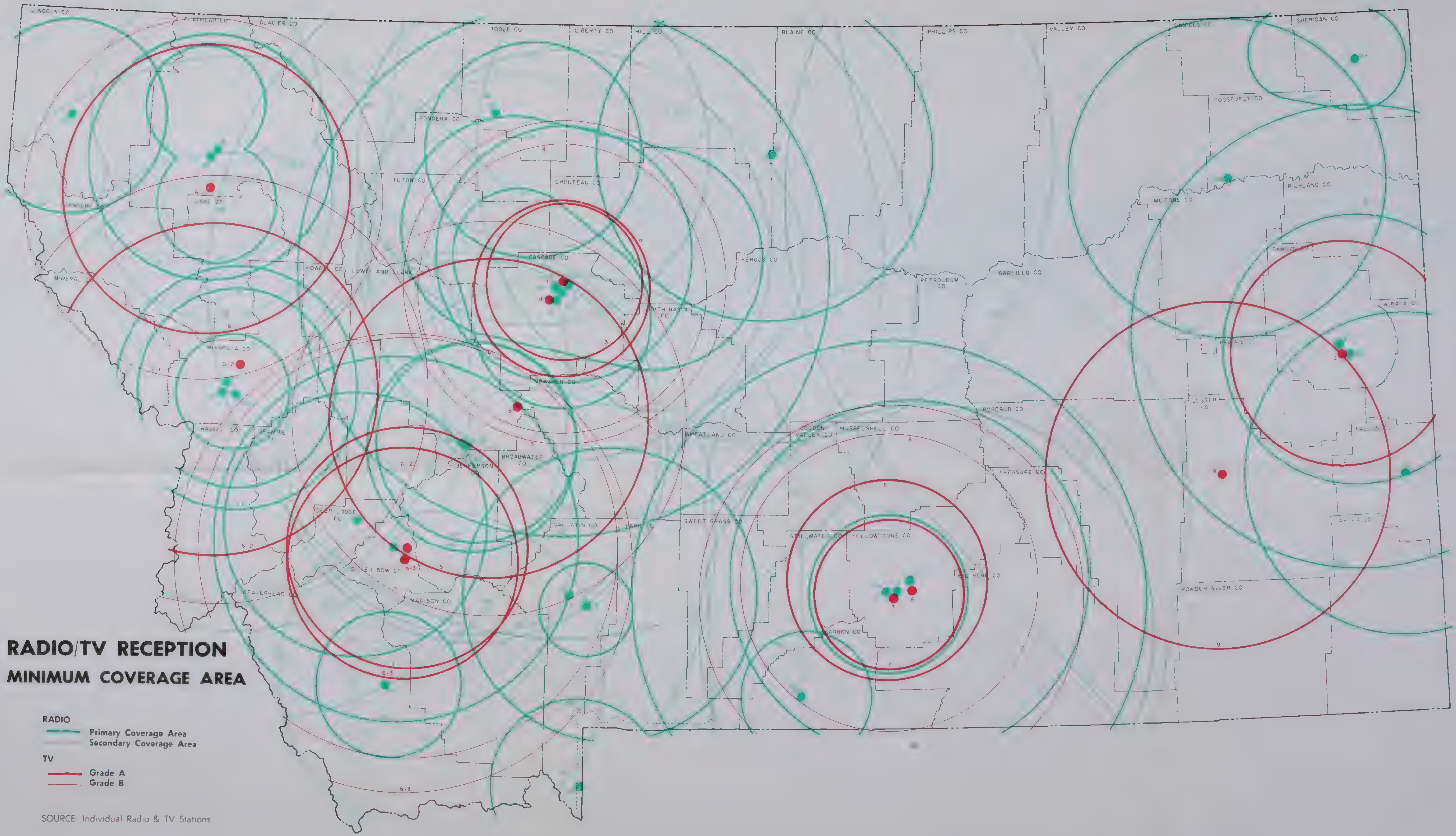
3) Take utmost care while stringing conductors to avoid burrs and scratches on conductors, to reduce audible noise RFI & TVI.

4) After selection of centerline location before the line is constructed, readings of radio and TV signals should be taken.

5) A post-energization instrumentation program should be developed to verify theoretical calculations of RFI, also TVI and audible noise. Interference, if due to the line, should be mitigated or should be eliminated by corrective steps.

4.4.2.2. Television Interference (TVI)

Discussion thus far has been of corona noise. Another type of noise associated with transmission lines is gap noise, resulting from a discharge current across the gap between the



RADIO/TV RECEPTION

MINIMUM COVERAGE AREA

RADIO

- Primary Coverage Area
- Secondary Coverage Area

TV

- Grade A
- Grade B

SOURCE: Individual Radio & TV Stations

conductor and another object, such as an insulator. Major causes of gap discharge are improper selection of insulators, poor line design, and improper maintenance. Each incidence of gap noise is of short duration and gives a high-amplitude pulse, resulting in a broadband noise of near-constant amplitude to very high frequencies. Gap noise can be prevented by proper line design (mainly number of conductors per phase, conductor diameter, etc.), good construction techniques, and proper maintenance.

Both gap noise and corona noise affect television video reception. Corona noise appears as a slowly moving horizontal band, covering about half of the television screen (Figure 4-13). Gap noise appears as long white streaks across the entire screen (Figure 4-14).

Besides corona and gap noise, the location of the transmission line in relation to both the broadcasting station antenna and the antenna of the consumer can influence reception quality. For example, if a directional television receiving antenna is pointed away from the transmission line in order to point toward the broadcast antenna or translator, interference will be minimal. If the receiving antenna points directly toward the transmission line in order to point toward the broadcast antenna, interference may be significant. Three different conditions are illustrated in Figure 4-15, 4-16 and 4-17. In condition one (Figure 4-15) the reception of transmitter "B" may be affected by the transmission line. In condition two, (Figure 4-16) interference can be mitigated by locating the transmission tower on the other side of buildings. In condition three (Figure 4-17) interference cannot be avoided. Thus distance and direction of the receiving antenna from the broadcasting antenna and from the transmission line is an important factor. Minimum levels of signal strength for television stations, established by the FCC are given in Table 4-5.

Table 4-5

Station Class	Channel No. 2-6	7-13	14-69
A	68 dbu or more	71 dbu or more	74 dbu or more
B	47 dbu or more	56 dbu or more	64 dbu or more

Relation of SNR to television reception quality is given in Table 4-6.

Table 4-6

Grade	Description of Reception	SNR
A	Excellent	37 db or higher
B	Very little interference	28 db to 36 db
C	Tolerable reception	17 db to 27 db
D	Interference very evident and annoying	4 db to 16 db
E	Intense interference	-12 db to 3 db

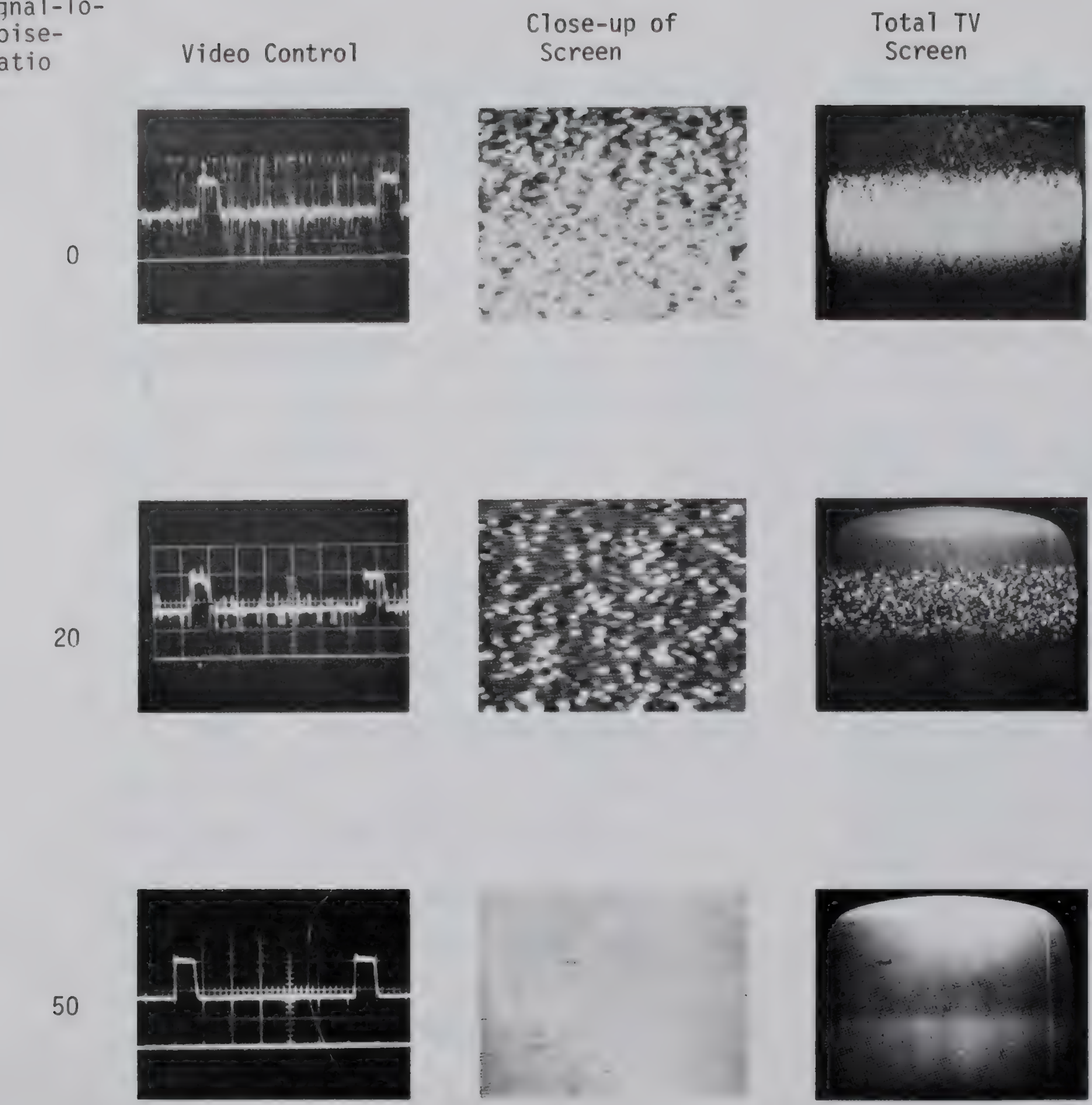


Figure 4-14: Effect of "Glow Noise" on Video-Control Voltage and Video Image for Different Signal to Noise Ratios

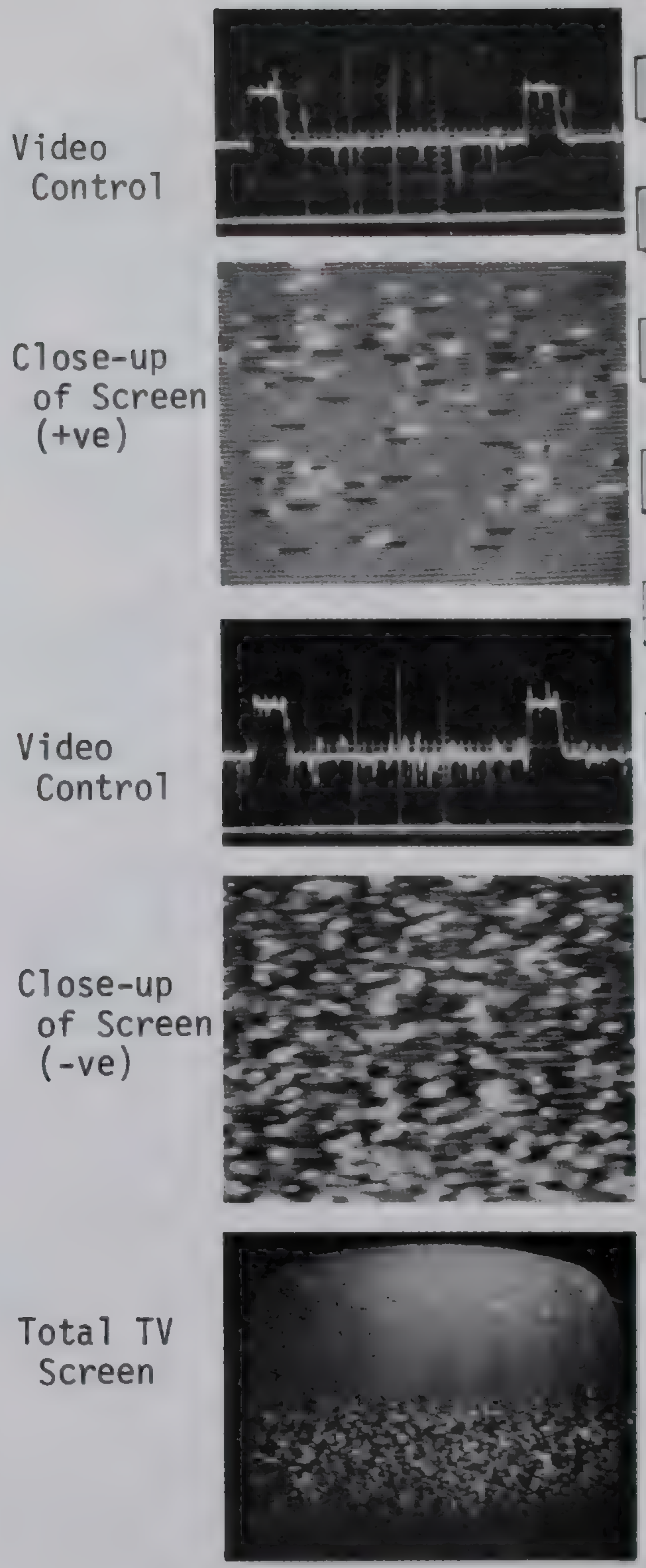
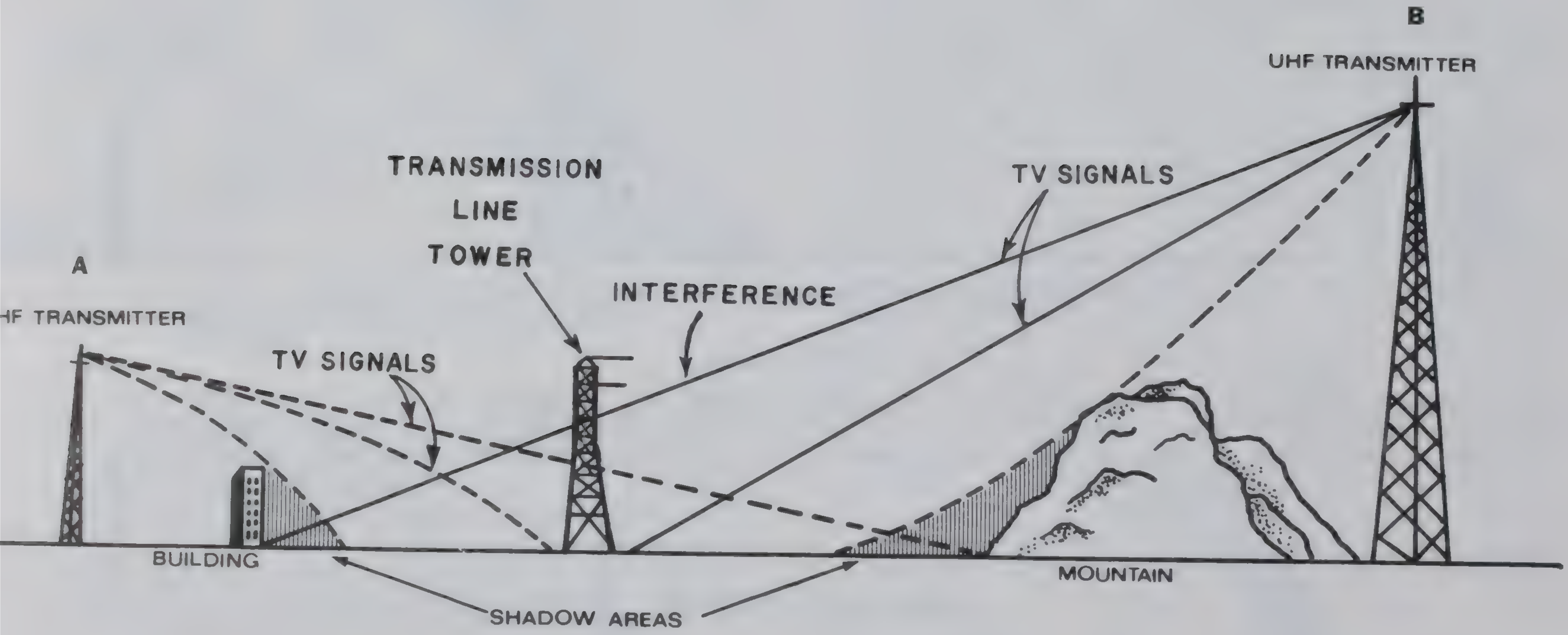
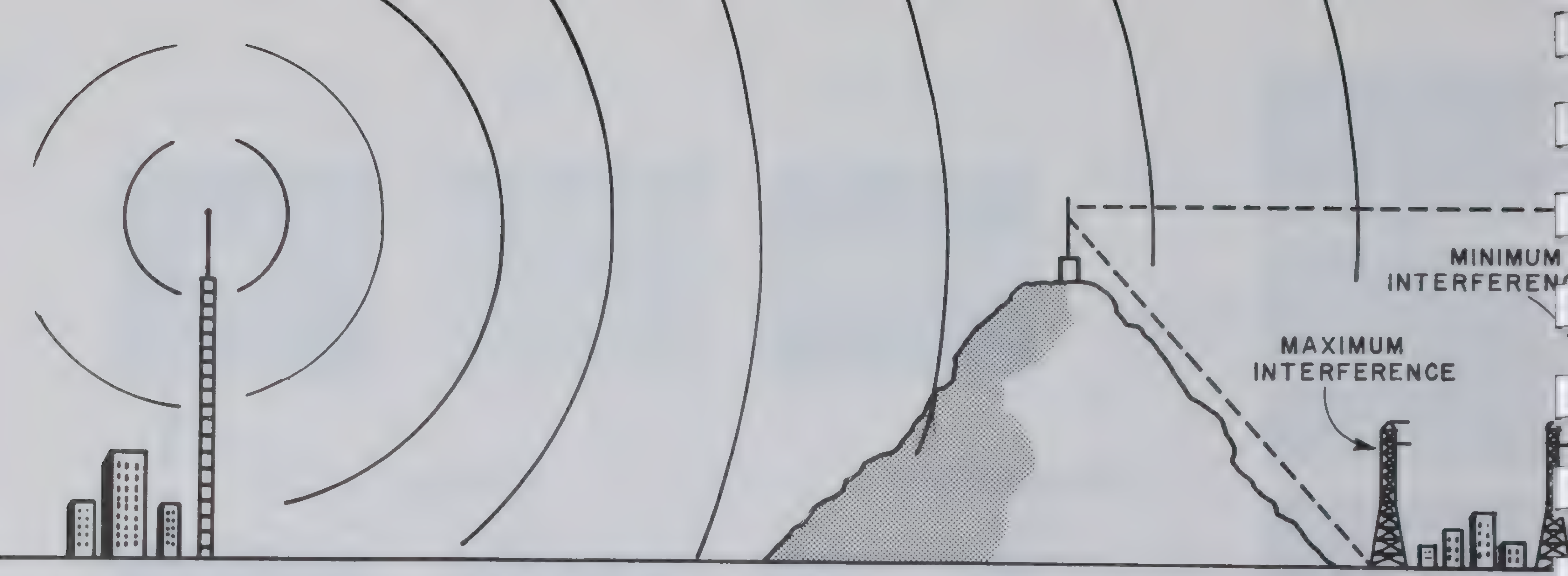


Figure 4-13: Effect of "Corona Noise"



UHF TRANSMITTER OPERATION
& POSSIBLE INTERFERENCE
CONDITION I

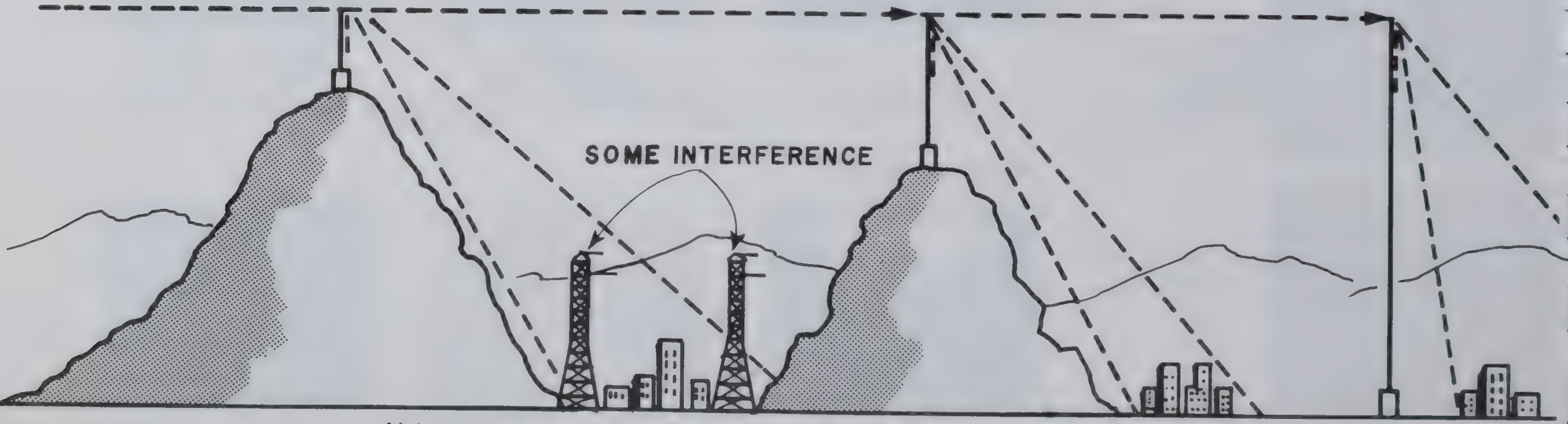
FIGURE 4–15



UHF TRANSLATOR OPERATION & POSSIBLE INTERFERENCE

CONDITION 2

FIGURE 4-16



MULTITOP SYSTEM OF TRANSLATOR STATIONS & POSSIBLE INTERFERENCE

CONDITION 3

FIGURE 4-17

A. Conclusion

Interference by the proposed transmission lines with forms of communication (including, besides radio and television, citizen's band radio, police radio, and channels between 25 and 60 mhz, used by industry) would vary depending upon distance of antennas from the lines, background noise, and signal strength. Determination of site-specific interference predictions would involve a case-by-case study. Figure 4-18 gives theoretical calculations to provide some idea of potential interference. The conclusion of RFI is applicable for TVI.

4.4.3. Electrostatic and Electromagnetic Induction

Induction is directly related to A.C. current and voltage, and can create such problems as hazardous shock. The proposed line would have a voltage level of 500,000 volts, and a current level that could get as high as 2,000 amperes per phase. Current and voltage of this magnitude could induce current and voltage in nearby conducting objects through mutual inductive coupling and capacitive coupling.

4.4.3.1. Mutual Inductive Coupling

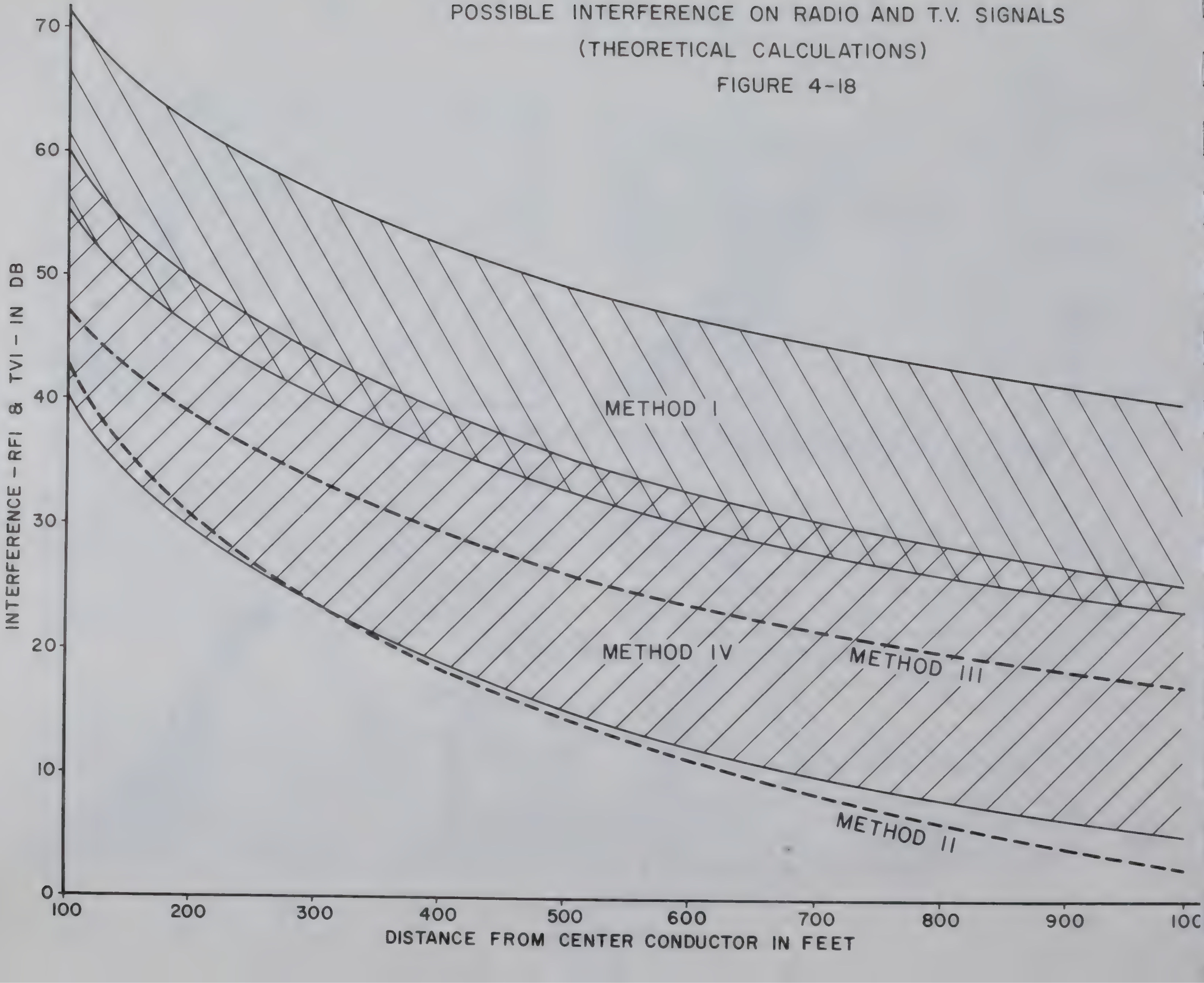
This occurs between power lines and a conducting object which is not properly grounded.

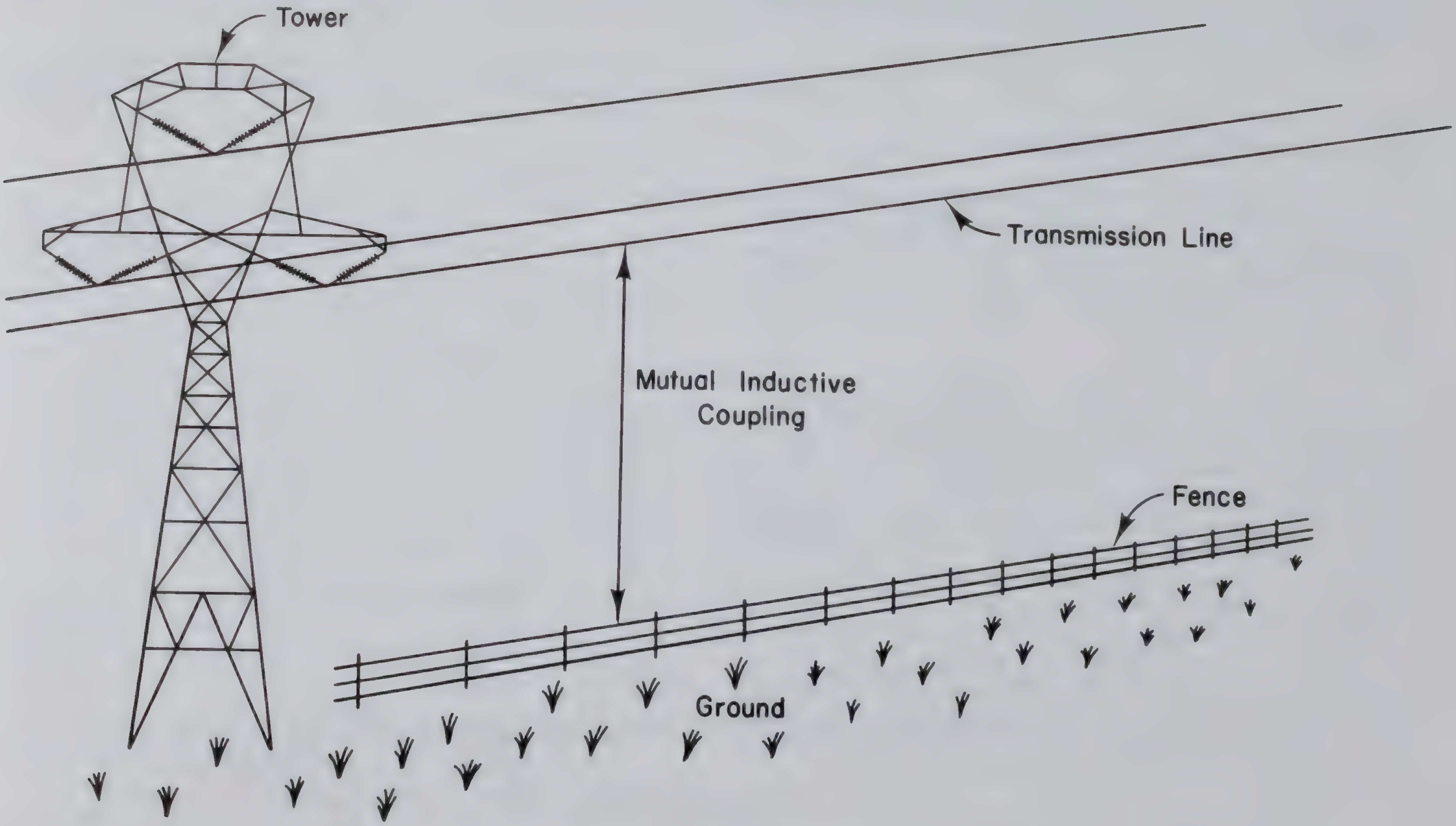
Current flowing in the power line sets up a magnetic field, the effect of which is limited to long conductors which are parallel and close to the line; the most commonly affected example is a wire fence (Figure 4-19). Voltage induced between the ends of the affected wire in the fence is the open-circuit voltage if the fence is not properly grounded. If the fence is grounded, it forms a closed circuit and induction is not a problem. If a person or animal touches a fence in which voltage has been induced, current flowing through the fence up to that point along the transmission line will flow through the person to the ground, reducing voltage in the fence up to the point of contact to zero; voltage will begin to build up again when contact between the person and the conducting object (fence) is broken. How effective and complete this flow of current to the ground is--and ultimately how serious the electrical shock to the person is--depends on the impedence of the return circuit through the earth, the resistance of the person touching the fence, how solidly contact is made with the conductor, at what point on the conductor contact is made, and the impedence of the fence itself. In Appendix I6, the worst case of mutual inductive coupling has been calculated for various locations of fences in relation to the transmission line.

A. Conclusion

The theoretical worst-case values of current induced in a fence by mutual coupling is 0.6 mA, given the proposed design of the twin 500 KV lines. Figure 4-21 (Effect of Current on Humans) gives some idea of the magnitude of the shock. The construction, maintenance, and instrumentation guidelines are covered in the following

POSSIBLE INTERFERENCE ON RADIO AND T.V. SIGNALS
(THEORETICAL CALCULATIONS)
FIGURE 4-18





MUTUAL INDUCTIVE COUPLING

FIGURE 4-19

section (4.4.3.2.). Present knowledge of these proposed designs does not indicate any inductive coupling problem.

4.4.3.2. Capacitive Coupling

This occurs between EHV power lines and a conducting object located on some insulating material; the most common incidence is between power lines and a rubber-tired vehicle located near the lines. Figure 4-20 is a model of capacitive coupling.

A person or animal touching a vehicle in which voltage has been induced by capacitive coupling will create a short circuit, since the capacitive impedence between the object and the ground is much higher than the impedence of the body. As induced voltage discharges through the body, and current passes through the body to the ground, a shock may be experienced or it may spark. If any metallic object (which is not grounded) is brought very close to or touches the vehicle, it may spark. For example, if a can of gasoline is brought to the vehicle for refueling, it may spark and ignite the gasoline. The amount of current discharged, and the degree of the shock or spark depends on these factors:

1) Position of vehicle in relation to power lines—whether it is parallel to the line or at an angle.

2) Insulation of vehicle--the poorer the insulation, the smaller the current.

3) Size of vehicle--the smaller the vehicle, the smaller the current.

The worst cases of capacitive coupling for the proposed lines have been calculated in Appendix I6.

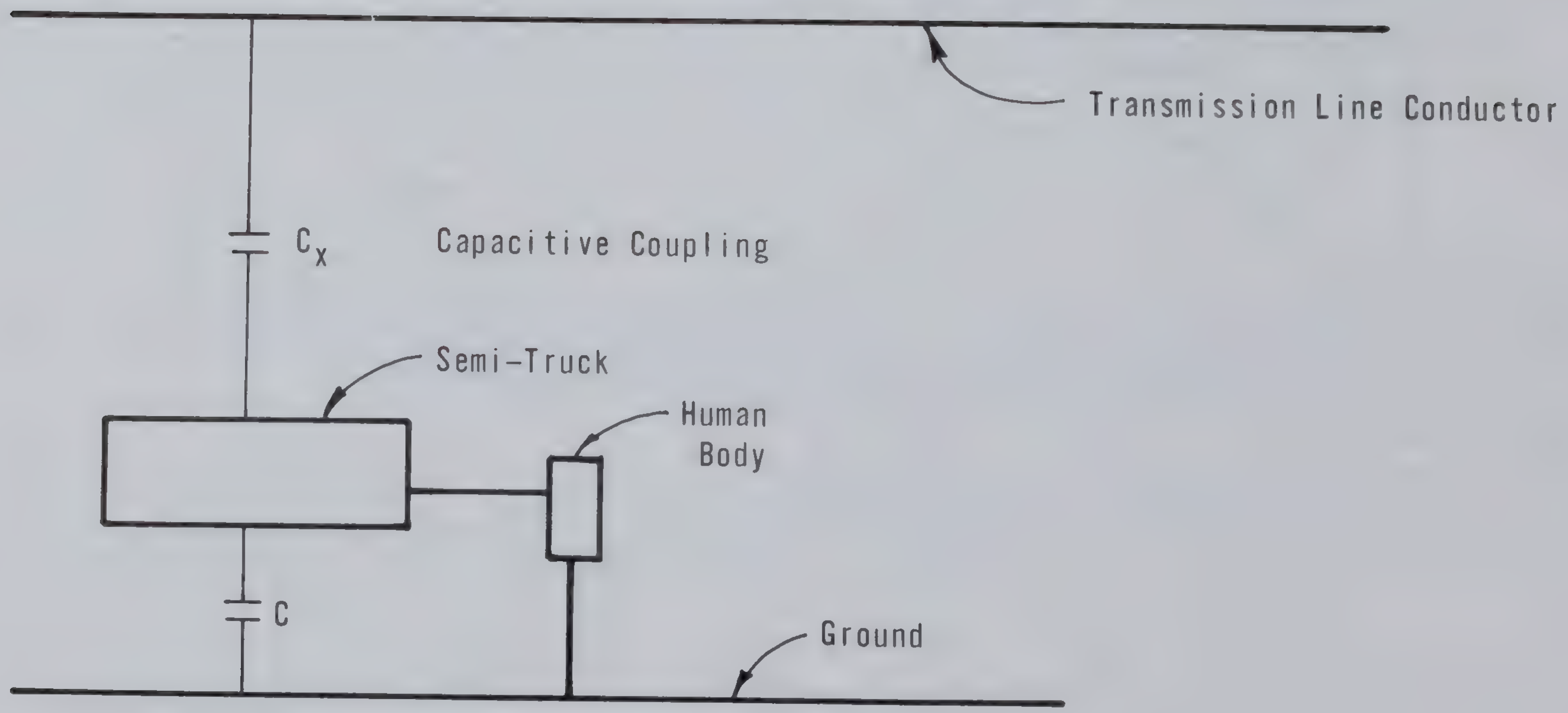
A. Conclusion

The theoretical worst-case (in foul weather, with a vehicle parked directly underneath the conductor at mid-span — 37' clearance) values of current induced in a parked car (Dimensions — H-5', W-5 .6', L-16') can be as high as 2.09 mA, and for a semi-truck (H-13.6', W-8', L-39') can be as high as 8.14 mA (see Appendix I6). The possibility of current reaching this value is considered to be remote. Figure 4-21 gives details of the effects of varying levels of current on humans. If the proposed twin 500 KV lines are approved, the following mitigative measures can be used to minimize the impacts:

1) Provide higher clearances in those areas where the use of heavy machinery is anticipated, to minimize electrostatic effects.

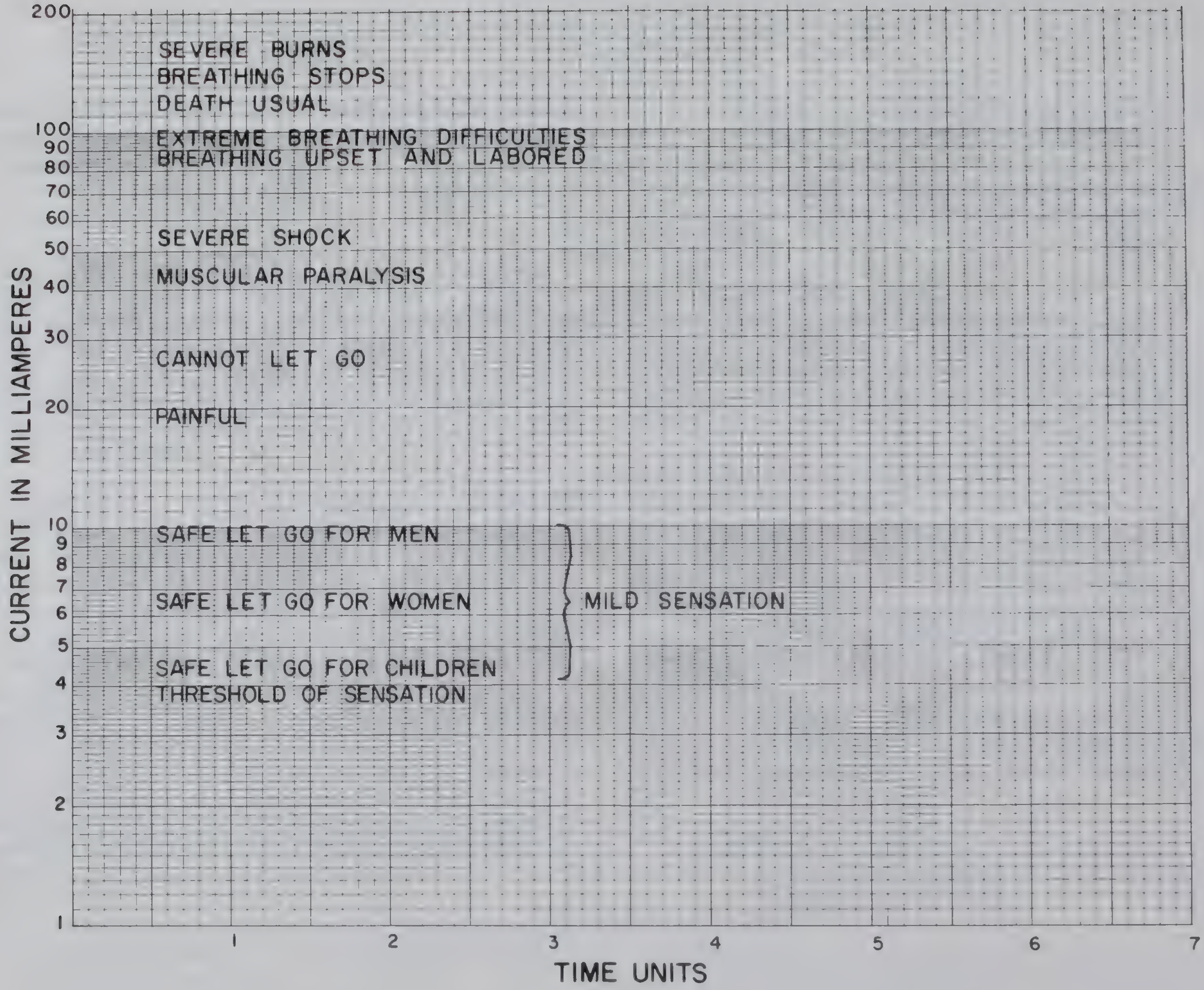
2) In proximity of transmission lines, ground fix objects such as metal structures, fences, etc.

3) An instrumentation and line supervision program should be developed to verify the electrostatic and electromagnetic effects, and, if warranted, corrective steps to mitigate or eliminate these



CAPACITIVE COUPLING

FIGURE 4-20



EFFECTS OF CURRENT ON HUMANS

Source: Popular Science, 1972 and Rene-Coma IEEE Paper

FIGURE 4-21

effects should be taken. Use of standard measuring equipment should be as suggested in OSHA (Occupational Safety & Health Act).

4) A ground level actual electrostatic profile should be developed using an "electrostatic meter". Vehicle short circuit currents, frequently encountered by moving vehicles, should be measured both during dry and wet ground conditions.

5) After lines are energized, the lines should be inspected periodically. The grounding of potentially dangerous metal objects in close proximity to the line should be verified. Whenever there is new metal construction in proximity to the line a check for grounding and safety should be made.

Precautions for landowners are as follows:

1) Do not try to stockpile material underneath the conductors or touching the towers.

2) Do not try to refuel cars or trucks underneath the conductors.

3) If sprinkler system is used, make sure the water is not touching the conductors even under worst conditions such as high wind effect.

4) Do not try to climb the towers or try to destroy insulators, conductors, or any part of the transmission line. This will increase all hazardous problems.

5) If any kind of problems (electrical shocks or RFI & TVI) arise, immediately inform the utility company and Department of Natural Resources and Conservation.

6) If any construction in the vicinity of the transmission line is required, talk to the utility company for proper grounding and safety requirements.

4.4.4. Electrochemical Reaction

As a result of energizing an EHV transmission line, the only potential product of electrochemical reaction that is likely to cause damage or concern is ozone (O_3). Concern has risen in recent years about the air polluting properties of this gas. In excess amounts ozone can cause human discomfort (in breathing), plant damage, damage to plastics and rubber, and can act as a chemical intermediary which may interact with other gases present in the air.

The major source of ozone is natural occurrence. It appears in the biosphere (an upward zone of the earth's gaseous covering) via vertical mixing with the ozone-rich stratosphere, and via photolysis of products of combustion and photosynthesis.

Ionization of air was discussed in Section 4.4.1. Free electrons, accelerated by discharge of electrical energy from power-line conductors, can excite oxygen molecules (O_{2e}), which, if they react with other oxygen molecules (O_2), might produce ozone:

$$O_{2_c} + O_2 \longrightarrow O_3 + O$$

This equation is theoretical. Further laboratory research is underway to assess the relationship of ozone production and corona discharge. Recent test results are discussed in Section 6.1.6., and the magnitude of the potential impact is discussed in that Section.

CHAPTER FIVE Study Area Analysis and Inventory

5.1. Natural Environment

5.1.1. Geology

5.1.1.1. Physiography

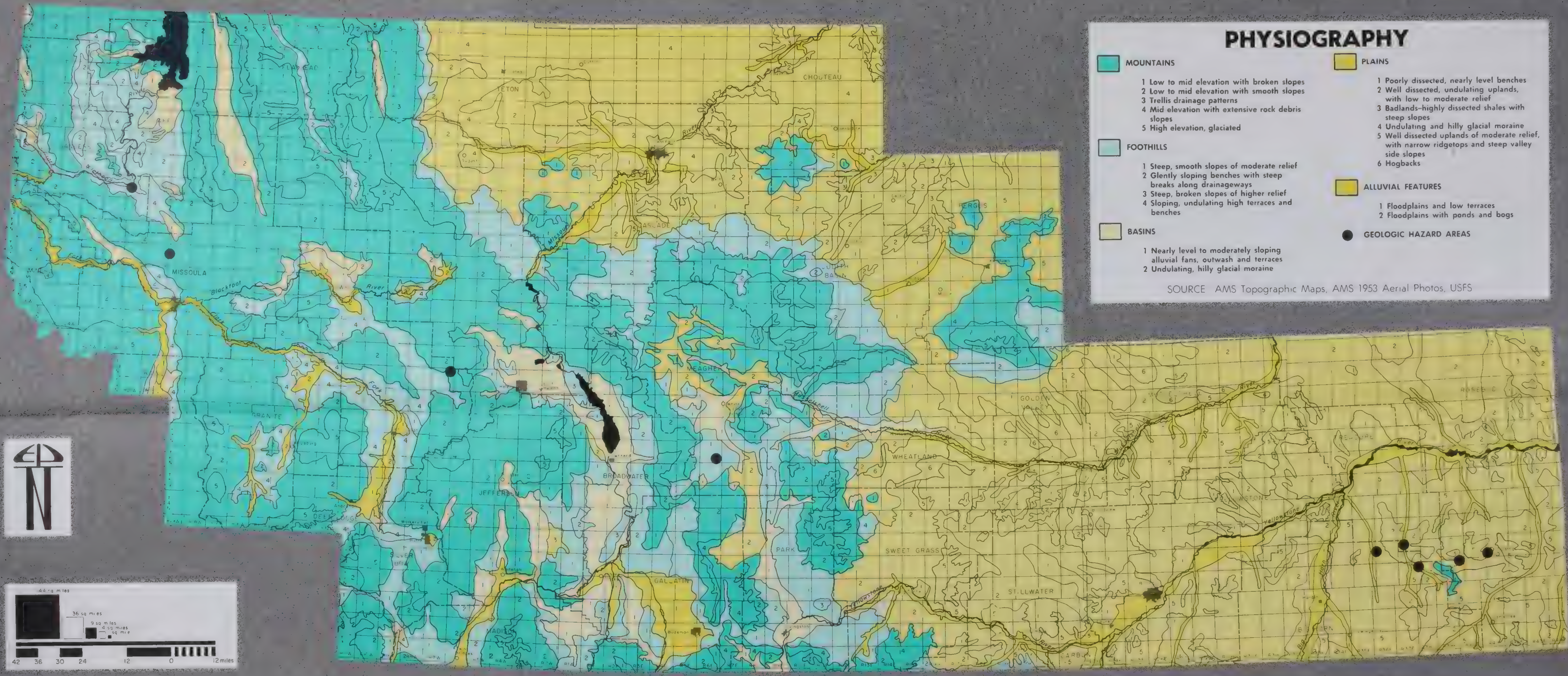
Landforms are the result of present and past geological processes acting upon the materials which compose the earth. Just as the geology of Montana is complex and diverse, so is the physiography. Physiography directly and indirectly affects the climate and all life in the state, including the activities and settlement patterns of man. Plant and animal distribution patterns, land use patterns, and factors which influence the cost of construction, all of which help determine the location of transmission lines, are controlled by physiography.

Eastern Montana is part of the Great Plains Province (Fenneman 1931) and is characterized by moderate to low relief, developed upon nearly flat-lying sedimentary rocks. Some of the mountains which lie in the plains are the result of uplifts in which tilted strata or igneous rocks are exposed. Other mountains, such as the Bull Mountains, are the result of differential erosion. Parts of eastern Montana consist of highly dissected uplands resulting in a diverse, attractive landscape.

Western Montana is part of the Northern Rocky Mountain Province and consists of numerous mountain ranges often separated by broad basins. In southwestern Montana, the mountains are generally separated from the basin-like valleys by faults along which the mountains rose and the valleys dropped. The mountains are composed of igneous, metamorphic and sedimentary rocks folded and otherwise deformed in complex ways. Many of these mountains have been glaciated. Faulting and differential erosion of the sedimentary terrain in northwestern Montana have produced lofty mountains and deep valleys. Both alpine and continental glaciation have strongly modified the physiography of this part of Montana.

The landforms of the study area have been separated into five categories: mountains, foothills, basins, plains, and alluvial lands. These categories have been further divided on the basis of physiographic or geologic characteristics and are shown on the Physiographic Map.

Mountains are those areas which rise conspicuously above adjacent valleys and basins. Since the term is subjectively defined, no rigorous definition in terms of elevation is applied here. Within the study area five types of mountainous areas are recognized. Foothills are the lower elevation equivalents of mountains, sometimes standing alone or bordering mountains. Four types of foothills are recognized. Basins are broad valleys enclosed by mountains which contain unconsolidated deposits other than those of flood plains and low terraces. Two categories of basins are recognized here. Lands of generally low relief and underlain by gently dipping sedimentary beds where the relief is mostly the result of erosional dissection are called plains. Six types of plains are mapped in the study area. Alluvial lands are those affected by flooding and/or a shallow water table, of which two kinds are


MISSOULA
FLATHEAD
LAKE
TETON
CHOUTEAU
CASCADE
FERGUS
JUDITH BASIN
MEAGHER
GRANITE
DEER LODGE
SILVER BOW
JEFFERSON
BROADWATER
PARK
GALLATIN
MADISON
GOLDEN VALLEY
WHEATLAND
SWEET GRASS
STILLWATER
YELLOWSTONE
CARBON
BIG HORN
ROSEBUD
Blackfoot River
Missouri River
Yellowstone River
Clark Fork
Musselshell
44 sq miles
36 sq miles
9 sq miles
4 sq miles
1 sq mile
42 36 30 24 12 0 12 miles
N

PHYSIOGRAPHY

🟩 MOUNTAINS
1 Low to mid elevation with broken slopes
2 Low to mid elevation with smooth slopes
3 Trellis drainage patterns
4 Mid elevation with extensive rock debris slopes
5 High elevation, glaciated
🟩 FOOTHILLS
1 Steep, smooth slopes of moderate relief
2 Gently sloping benches with steep breaks along drainageways
3 Steep, broken slopes of higher relief
4 Sloping, undulating high terraces and benches
☐ BASINS
1 Nearly level to moderately sloping alluvial fans, outwash and terraces
2 Undulating, hilly glacial moraine
🟨 PLAINS
1 Poorly dissected, nearly level benches
2 Well dissected, undulating uplands, with low to moderate relief
3 Badlands–highly dissected shales with steep slopes
4 Undulating and hilly glacial moraine
5 Well dissected uplands of moderate relief, with narrow ridgetops and steep valley side slopes
6 Hogbacks
🟨 ALLUVIAL FEATURES
1 Floodplains and low terraces
2 Floodplains with ponds and bogs
● GEOLOGIC HAZARD AREAS

SOURCE AMS Topographic Maps, AMS 1953 Aerial Photos, USFS

mapped. The following series of photographs illustrates typical views of the units shown on the Physiographic Map (Figures 5-1 through 5-17).

5.1.1.2. Other Geologic Parameters

The geologic materials that occur in the study area are bedrock and unconsolidated deposits (see Appendix K-3, Stratigraphy and Igneous Rocks). Bedrock varies significantly in harness and strength. In general, argillites, carbonates, igneous rocks, quartzites, and sandstones which occur within the study area are hard and strong, require blasting for excavation, and are capable of supporting lofty cliffs. Shale, however, is soft, weak, and easily excavated or eroded. Rock strength is frequently reduced by the presence of bedding planes and fractures.

Unconsolidated deposits occupy virtually all stream valleys. In the western part of the study area these deposits are in the form of Tertiary age valley fill, and Quaternary age glacial and alluvial deposits. Elsewhere, valley deposits are mainly recent alluvial. Alluvial gravels of Cenozoic age also occur in broad areas near the Snowy Mountains and in other, smaller patches throughout the plains region. A thin layer of weathered rock debris, or regolith, covers much of the areas underlain by bedrock. Some rocks, notably granite have very thick regolith in older, unglaciated terrains. Many steeper hillsides, especially in mountain areas, contain talus deposits of broken rock that have tumbled down from higher uphill.

Economic geologic materials extracted from the study area (see Appendix K-4, Economic Geology) include metals, nonmetals, and fuels (oil, gas, and coal). With the exception of the Butte mining district, where extensive deposits of low-grade copper ore are extracted by open pit methods, all metal mines are underground operations. Historically, much gold has been removed from placer, or stream-concentrated deposits, but the richer of these have now been exhausted, and placer deposits are no longer actively exploited. Oil and gas accumulations occur in localized stratigraphic and structural traps scattered throughout the plains portion of the study area. Most of the economically exploitable coal reserves in Montana are in the Fort Union formation of eastern Montana where thick, shallow, flat-lying deposits lend themselves to removal by strip mining.

Certain well-displayed geologic features provide significant insight into geologic processes or geologic history, and are of considerable current or potential interest to both geologists and non-geologists. The area of giant ripple marks impressively displayed south of Hot Springs is among these features. The ripples reveal catastrophic draining of prehistoric Lake Missoula, which occupied most of the major valleys in northwestern Montana during glacial times. Similarly, a classic terminal moraine south of Arlee impressively illustrates how a mountain glacier is able to erode and transport rock debris. These and other geologic features of public interest are included in the inventory of scenic and recreational localities found in Section 5.2.1.1., and are indicated on the Recreation Map. People who know of additional features are encouraged to submit them to the Energy Planning Division.

Wide variability exists in the kinds and characteristics of geologic materials that occur in the study area. Also, many of the geologic formations shown on the General Geology Map exhibit widely differing properties at different localities, dependent both on characteristics inherent to the deposits, and on special, localized circumstances, such as ground water or physiography. Further discussion of geologic features in the study area is presented in Appendix K.

Due to limitations of available information, geologic elements that are of environmental concern in transmission line construction are frequently difficult to identify. Mass movement hazards, such as landslides, are difficult to foresee, although some areas where these events have occurred in the past may be readily identified. Also, some potential geologic conflict areas are so localized as to be unimportant in selection of a two mile-wide corridor.

5.1.1.3. Seismicity

Destructive earthquakes are dramatic examples of a dynamic geologic process. Whole cities and thousands of persons have perished in large shocks, making earthquakes among the most feared natural phenomena. Although thousands of tremors occur each year, most are too small or remote to be destructive. Since the 1860's, more than 1000 earthquakes have occurred in Montana, but only a few caused extensive damage (Scott 1936 and Stewart et al. 1964).

Montana lies in the intermountain seismic belt, one of the more active earthquake zones in the United States (Smith and Sbar 1974). Large quakes can disable electrical generating plants by damaging the plant itself or its associated facilities. Therefore, seismic hazards should be evaluated and considered in the planning of the proposed facilities.

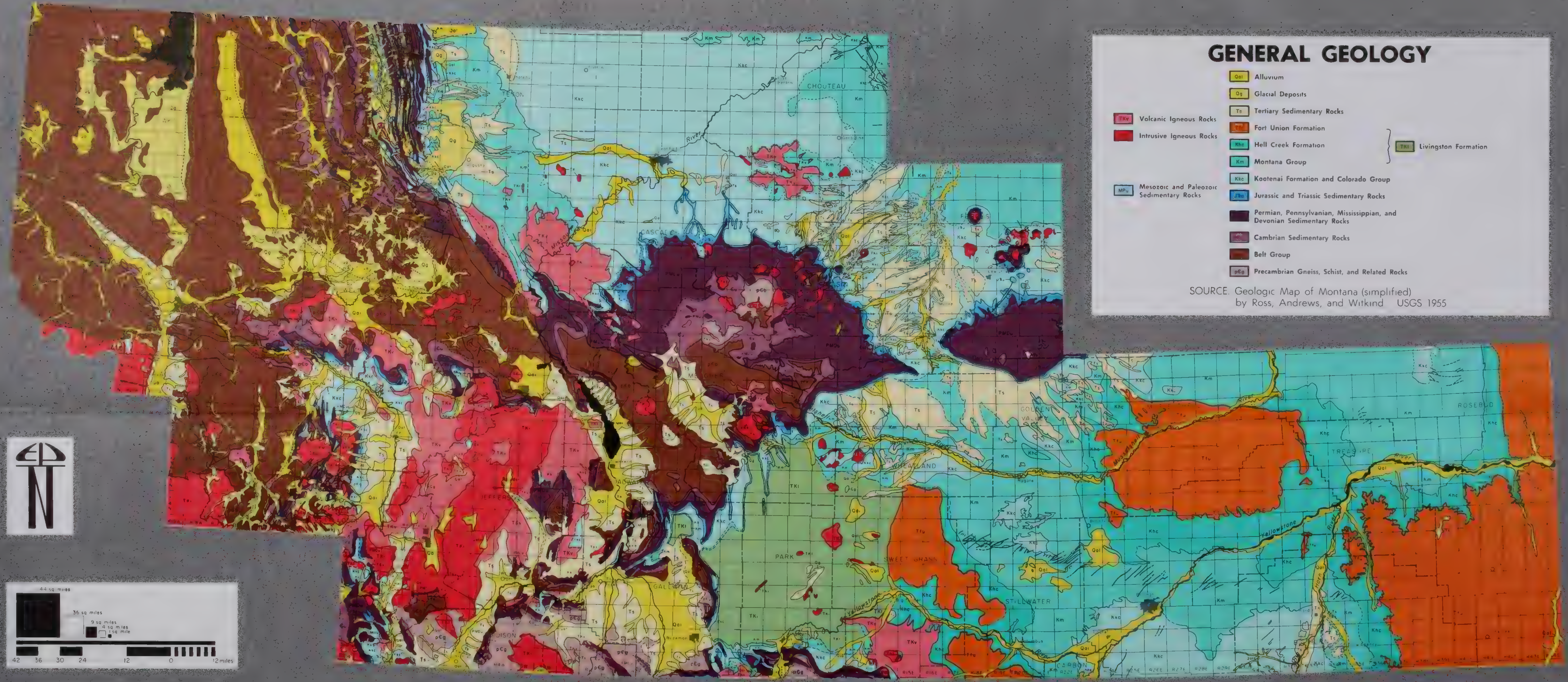
The San Fernando, California, earthquake of 1971 (magnitude 6.4) caused $25 million damage to power systems, including damage to thirty transmission towers ($160,000), one D.C. converter ($20 million), and transmission substations (Palk and Hanson 1973).

Causes of earthquakes include man-made explosions, cave-in's, rockfalls, volcanic explosions and meteorite impacts. Nearly all destructive shocks, however, are caused by sudden movement along faults (Fraser 1964).

Relative motion of parts of the earth's crust stresses the boundaries of these areas. Rock strength and friction prevent continuous motion. The shearing stresses produce an elastic strain which is released along a fault when the stress overcomes the strength of the rock. The energy of the suddenly released strain is converted into movement along the fault and is propagated as seismic waves. An area experiences an earthquake as the seismic waves vibrate the ground in passing (Howell 1959).

Earthquake intensity is a qualitative indicator of the violence of a quake as determined by its effect upon people and man-made structures, and by visible changes it causes in the earth. The Modified Mercalli scale (Table 5-1) is used to express intensity.

GENERAL GEOLOGY



SOURCE. Geologic Map of Montana (simplified)
by Ross, Andrews, and Witkind USGS 1955

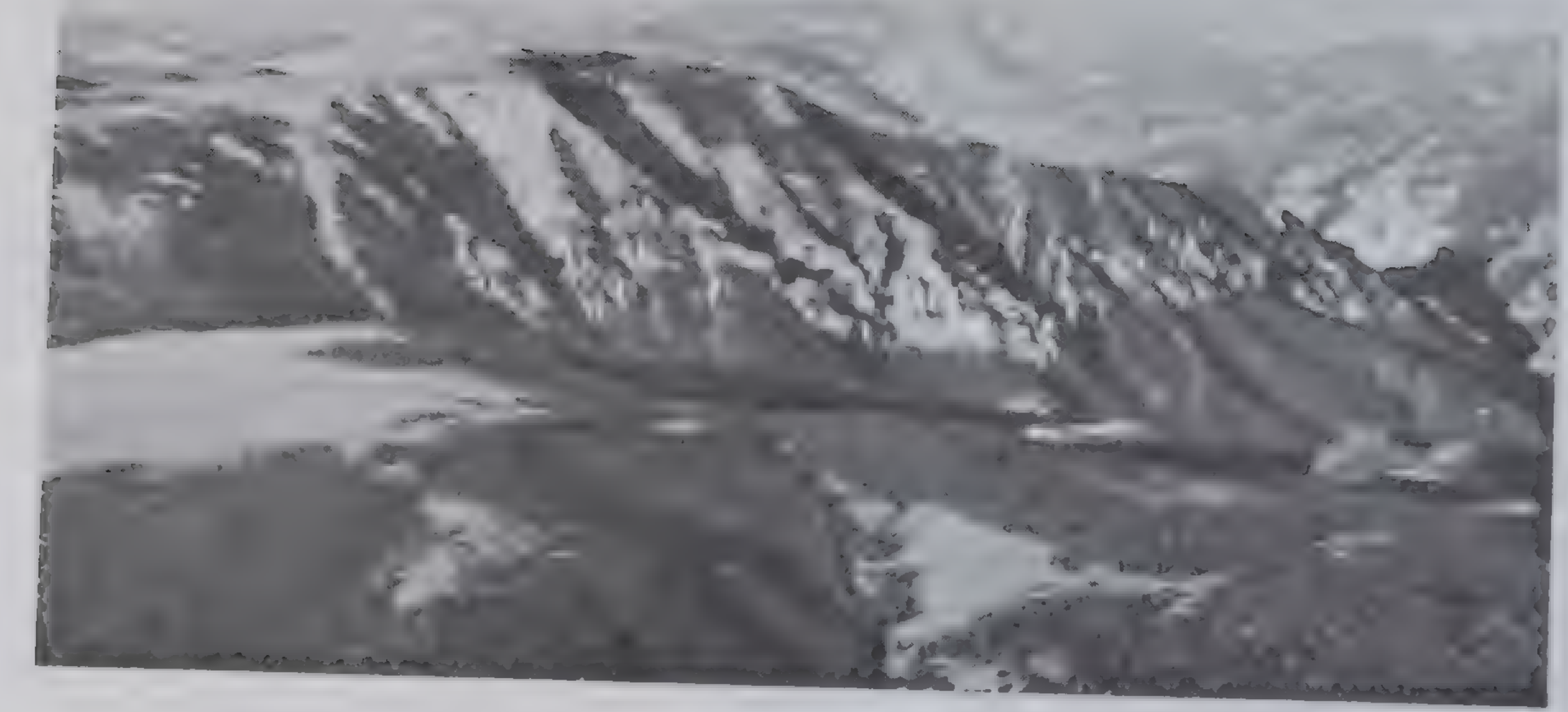
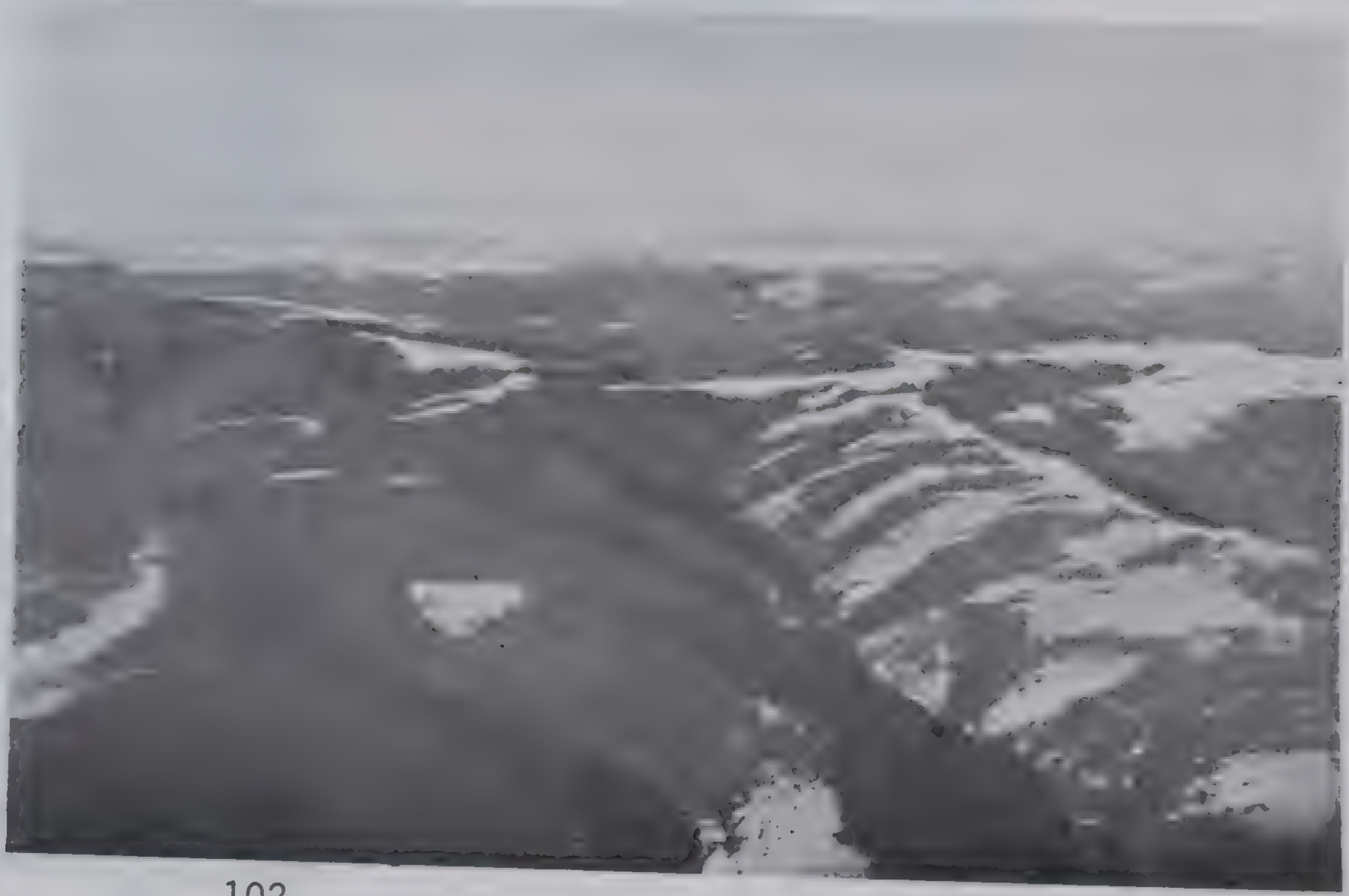


Figure 5-1

'1-1. Low to mid-elevation mountains with broken slopes.

Figure 5-2

'1-2. Low to mid-elevation mountains with smooth slopes.



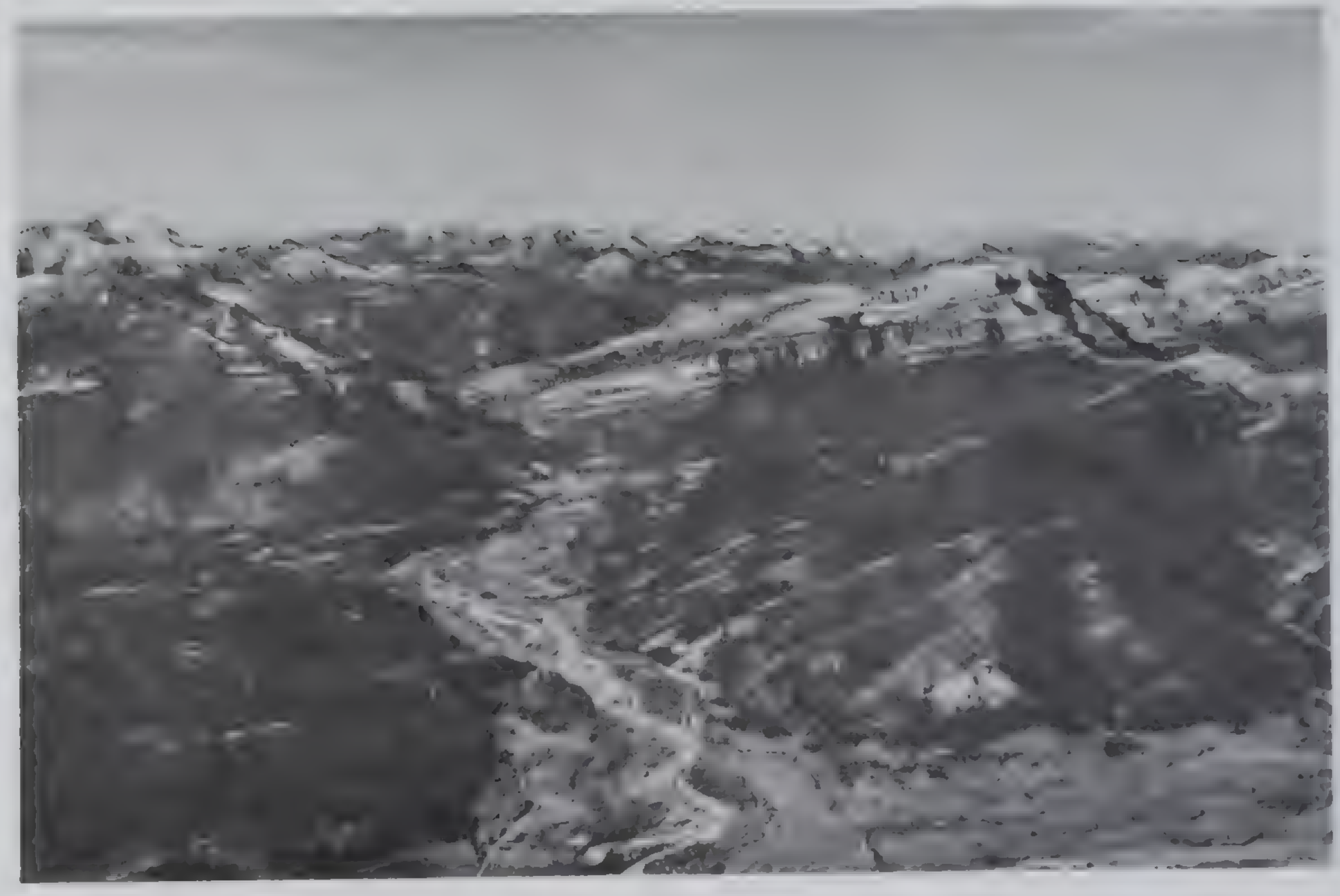


Figure 5-3

M-3. Mountains with parallel drainages resulting from imbricate overthrusting which has repeated layers of resistant and non-resistant strata.

Figure 5-4

M-4. Mid-elevation, high-relief mountains of soft rock, containing landscapes with significant areas of bedrock mass failure.

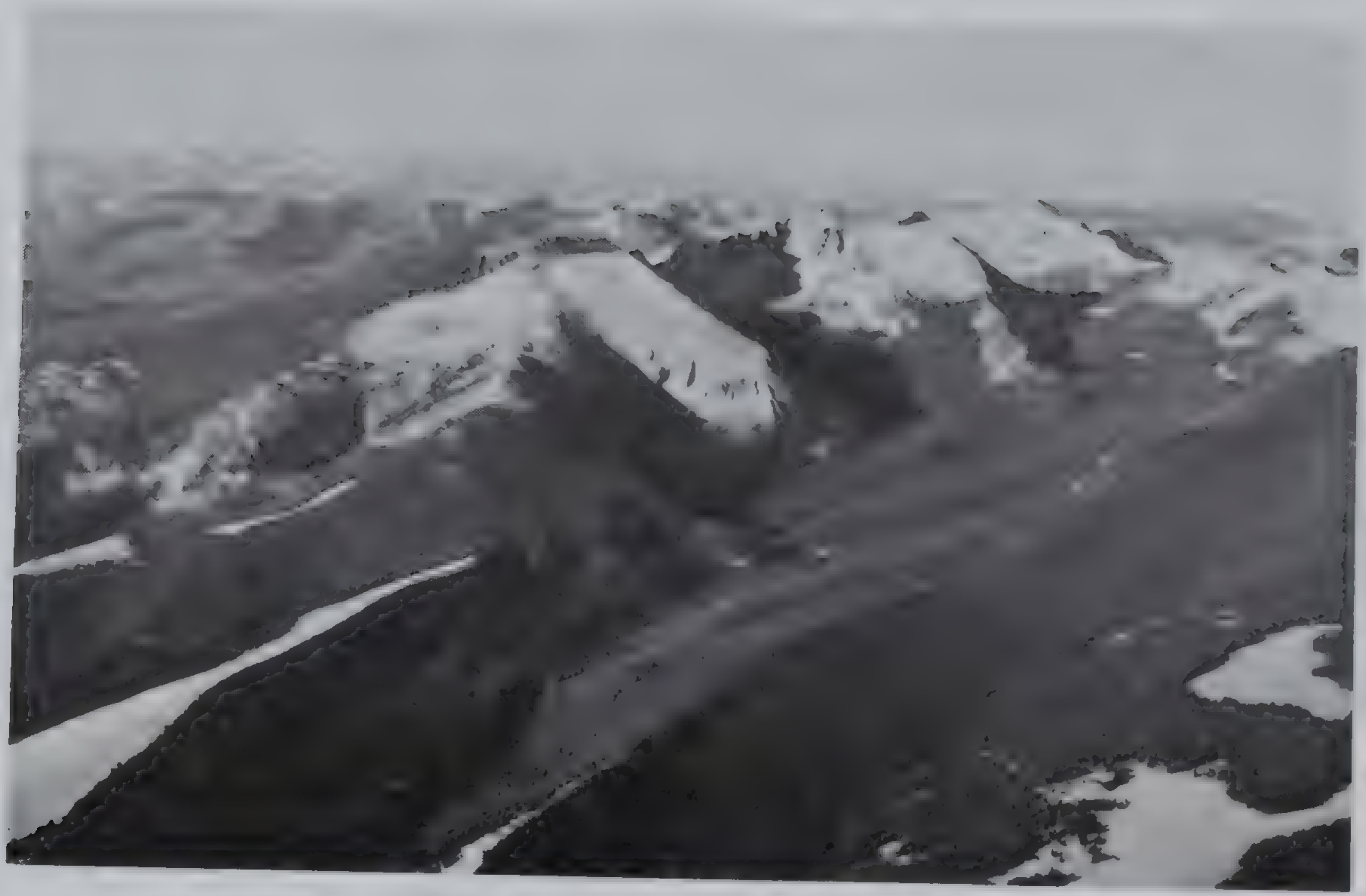
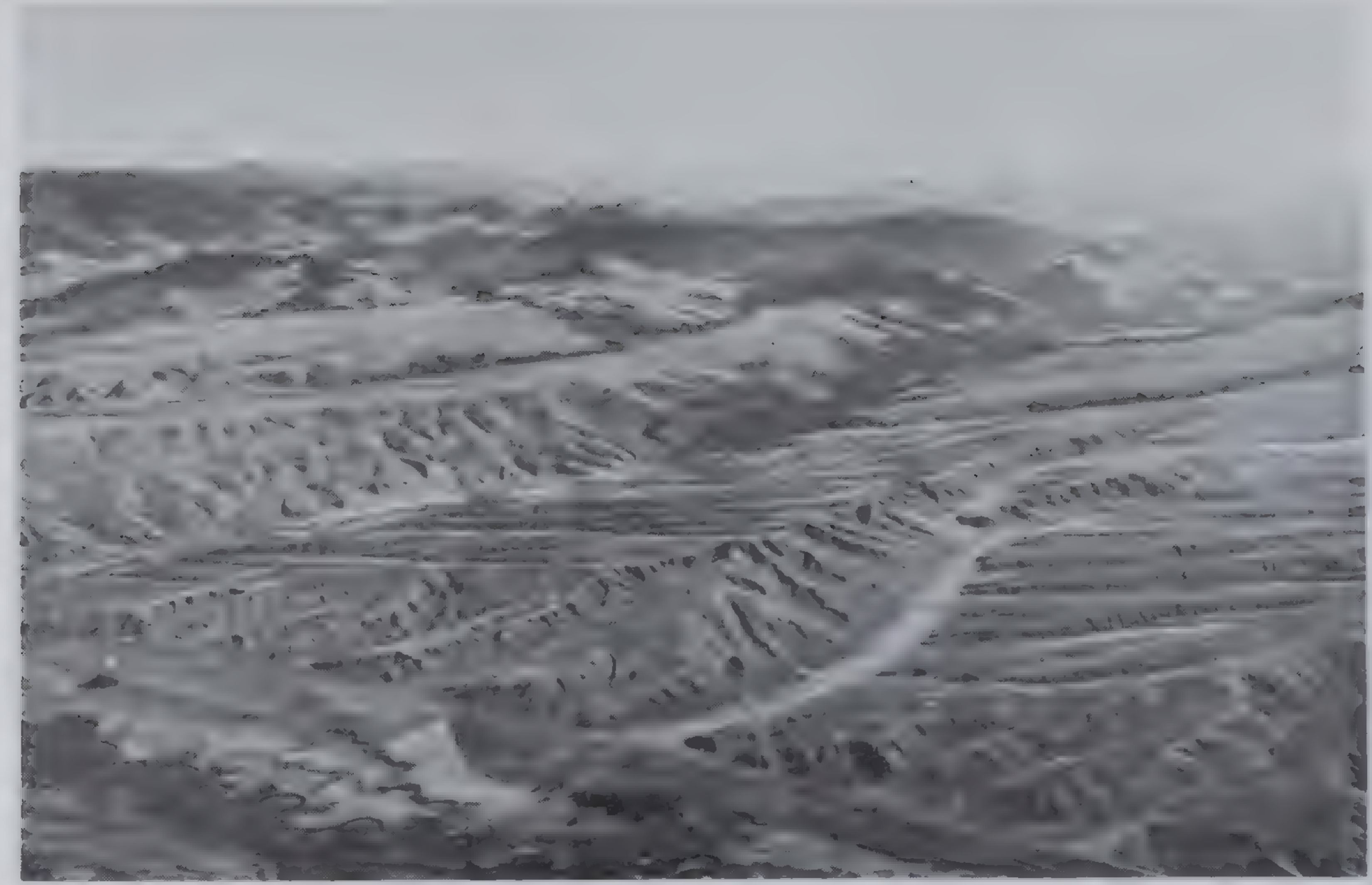


Figure 5-5

M-5. High elevation, glaciated mountains with steep slopes and great relief.



Figures 5-6

F-1. Steep, hilly, rounded foothills of moderate relief. Mainly moderately dipping sedimentary beds, with minor areas of weakly dissected, volcanic rocks.

F-2. Nearly level to gently undulating broad plateaus capped by gravel or resistant sedimentary rock, or clayey, unconsolidated Tertiary sediments or glacial Lake Missoula sediments. Steep breaks along drainages. Physiographically closely related to P-1, plains benchland, and where these units occur adjacent to one another the separation is somewhat arbitrary (not illustrated).

Figure 5-7

F-3. Very steep, broken lands of high relief formed by steeply dipping sedimentary beds that form hogback ridges.

F-4. Well dissected, undulating gravels and dipping shales and siltstones. Physiographically closely related to P-2, rolling plains uplands (not illustrated).

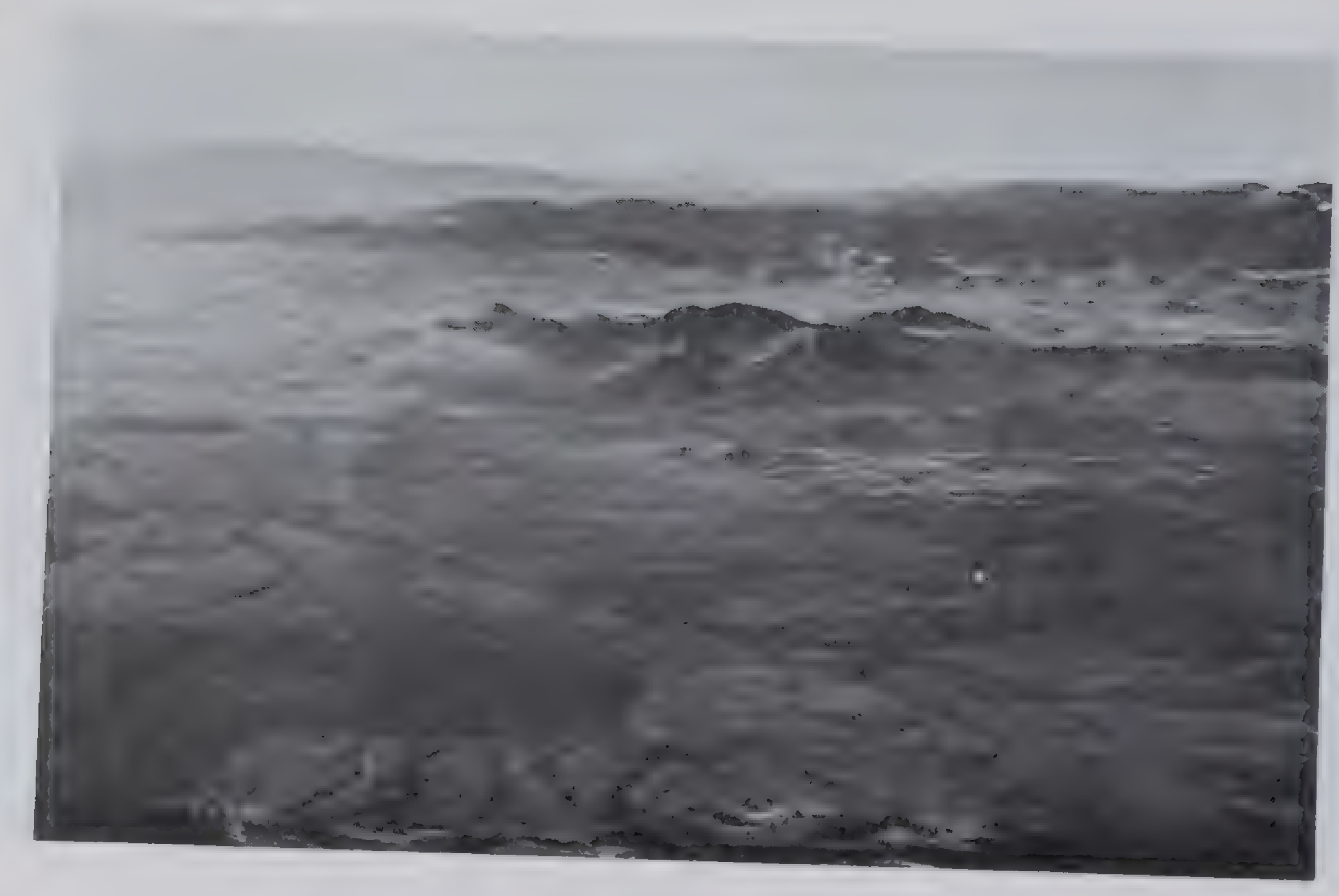
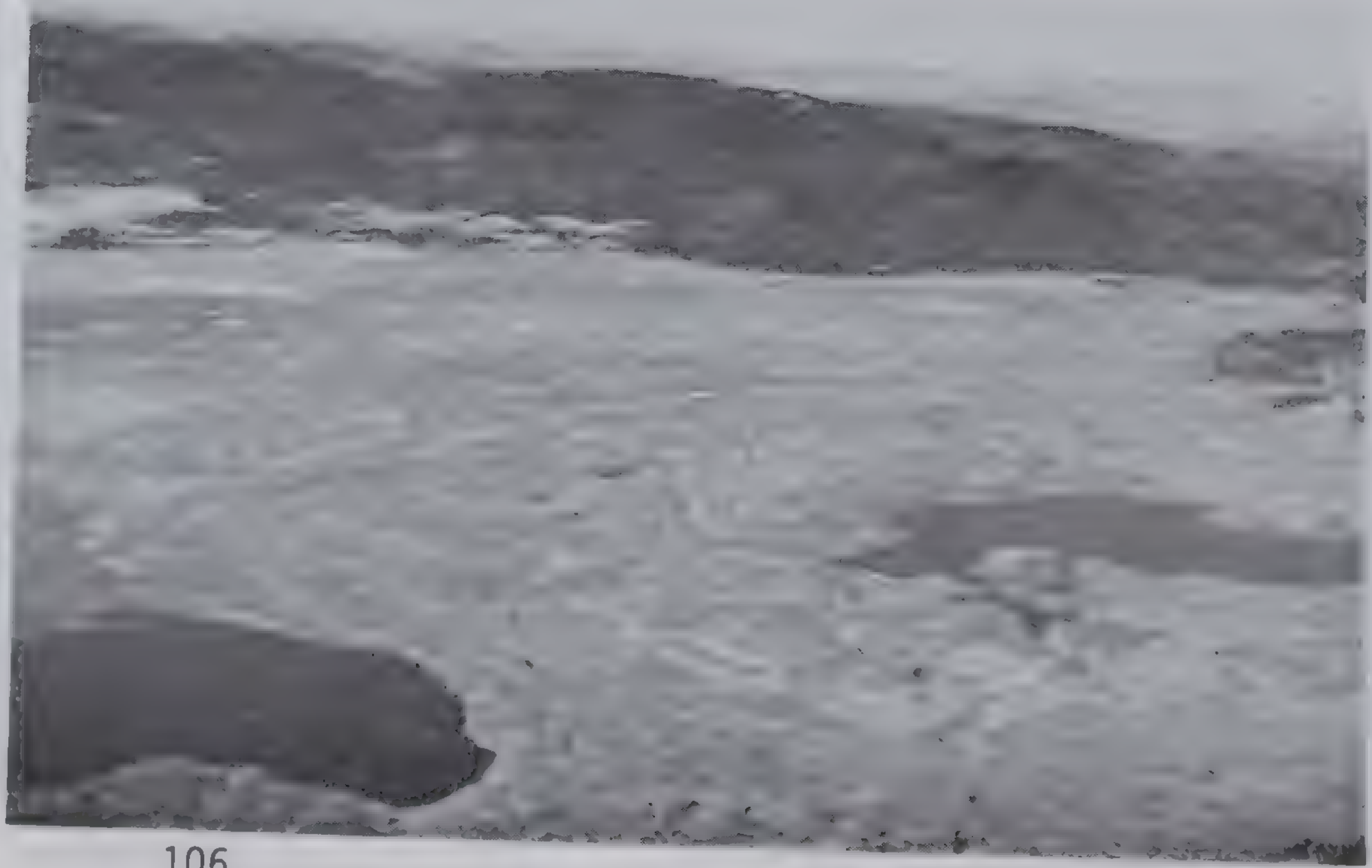


Figure 5-8

B-1. Gravelly, sandy alluvial fans and terraces sometimes containing glacial outwash surfaces. Mostly low relief.

Figure 5-9

B-2. Undulating to hilly glacial moraine. Physiographically related to P-4, glaciated plains.



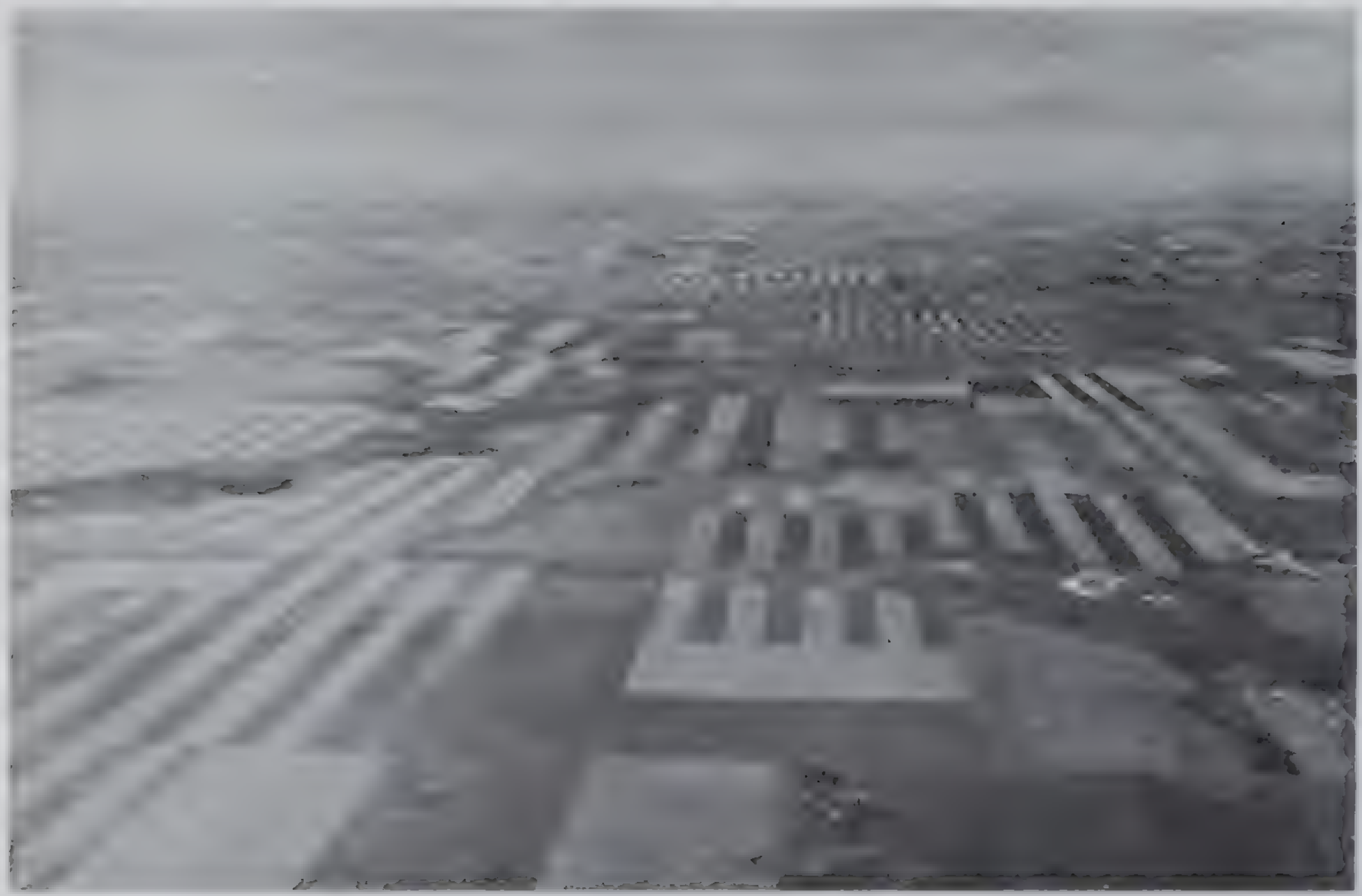
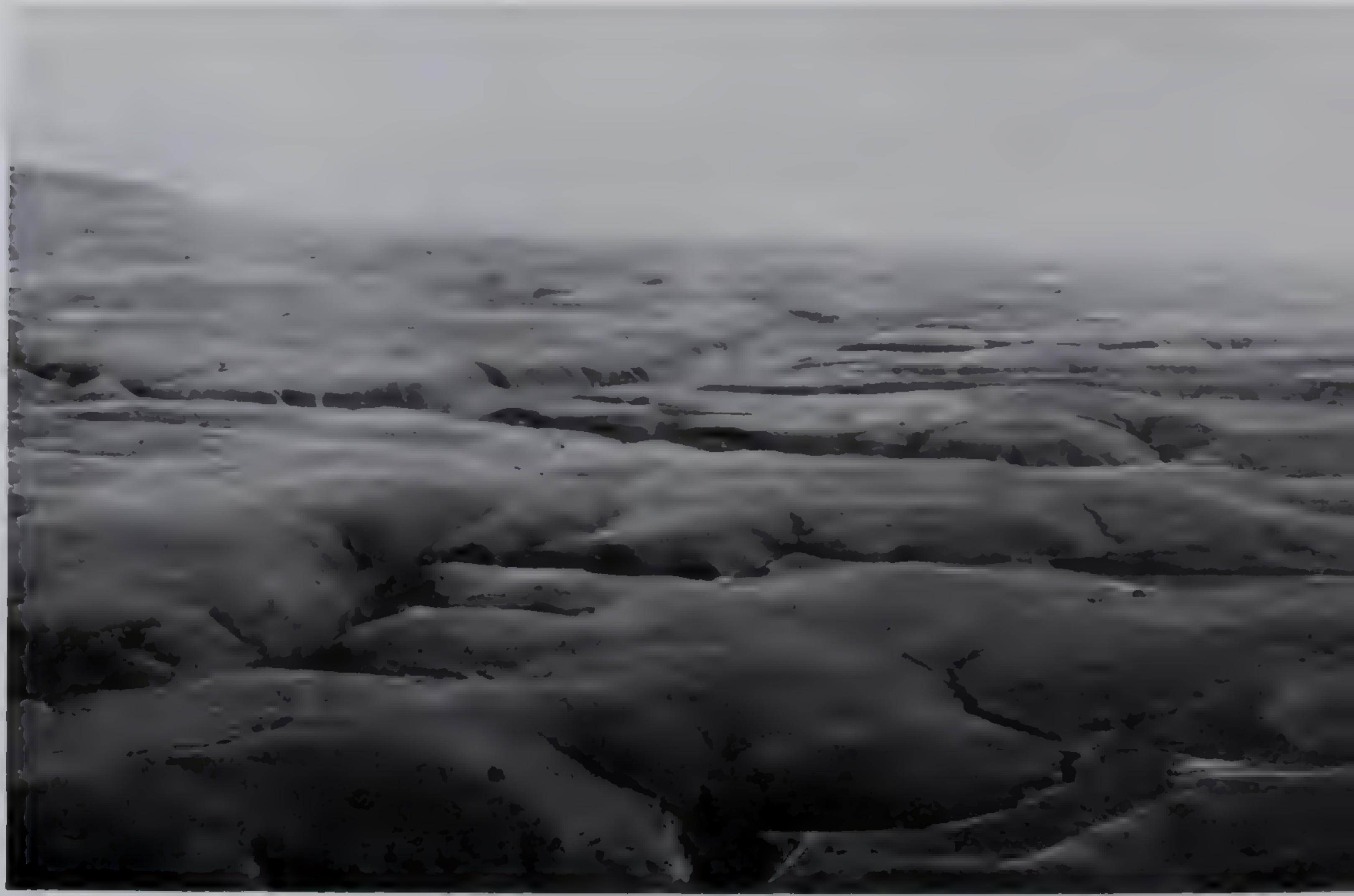


Figure 5-10

P-1. Poorly dissected plains benchland. Broad, nearly level or undulating benches several miles to scores of miles wide, with short, steep breaks along drainages.

Figure 5-11

P-2. Rolling plains uplands. Well dissected, rolling shale uplands formed by the erosional dissection of soft sedimentary rocks of uniform resistance to erosion. Low relief.



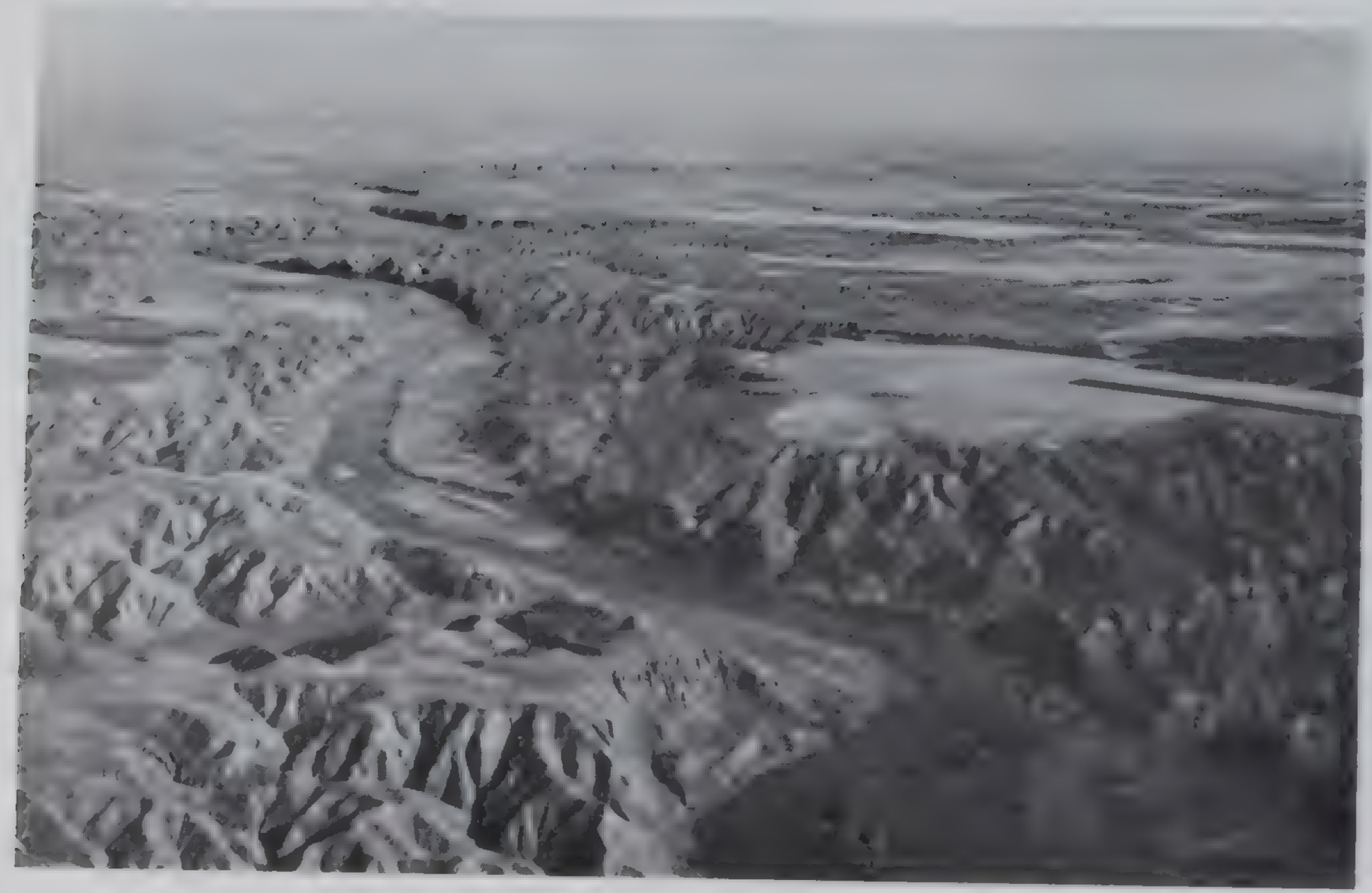
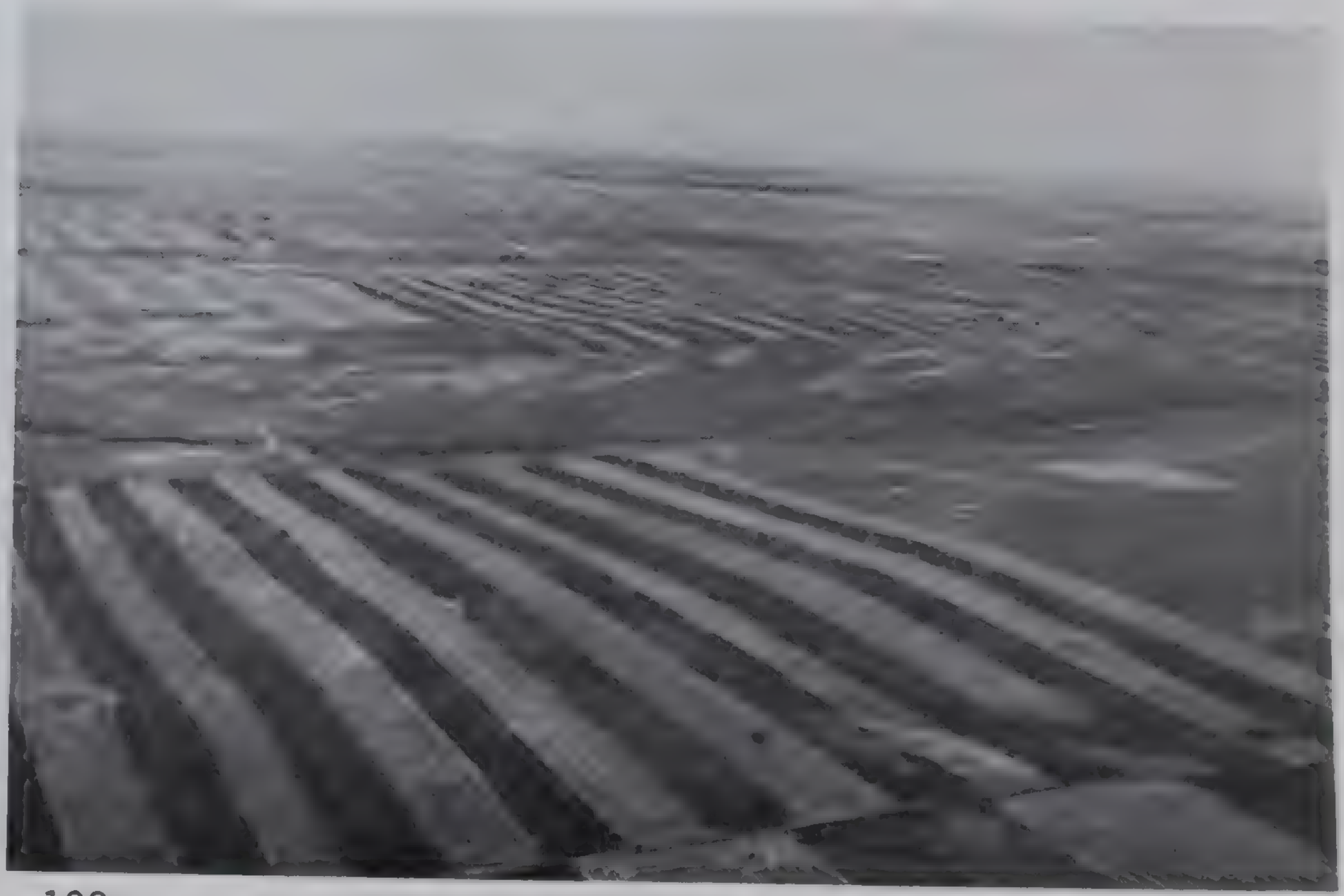


Figure 5-12

P-3. Badlands of moderate to high relief formed by dissection of soft bedrock, usually adjacent to major streams.

Figure 5-13

P-4. Glaciated plains. Undulating to rolling, poorly dissected uplands that have been subjected to continental glaciation.



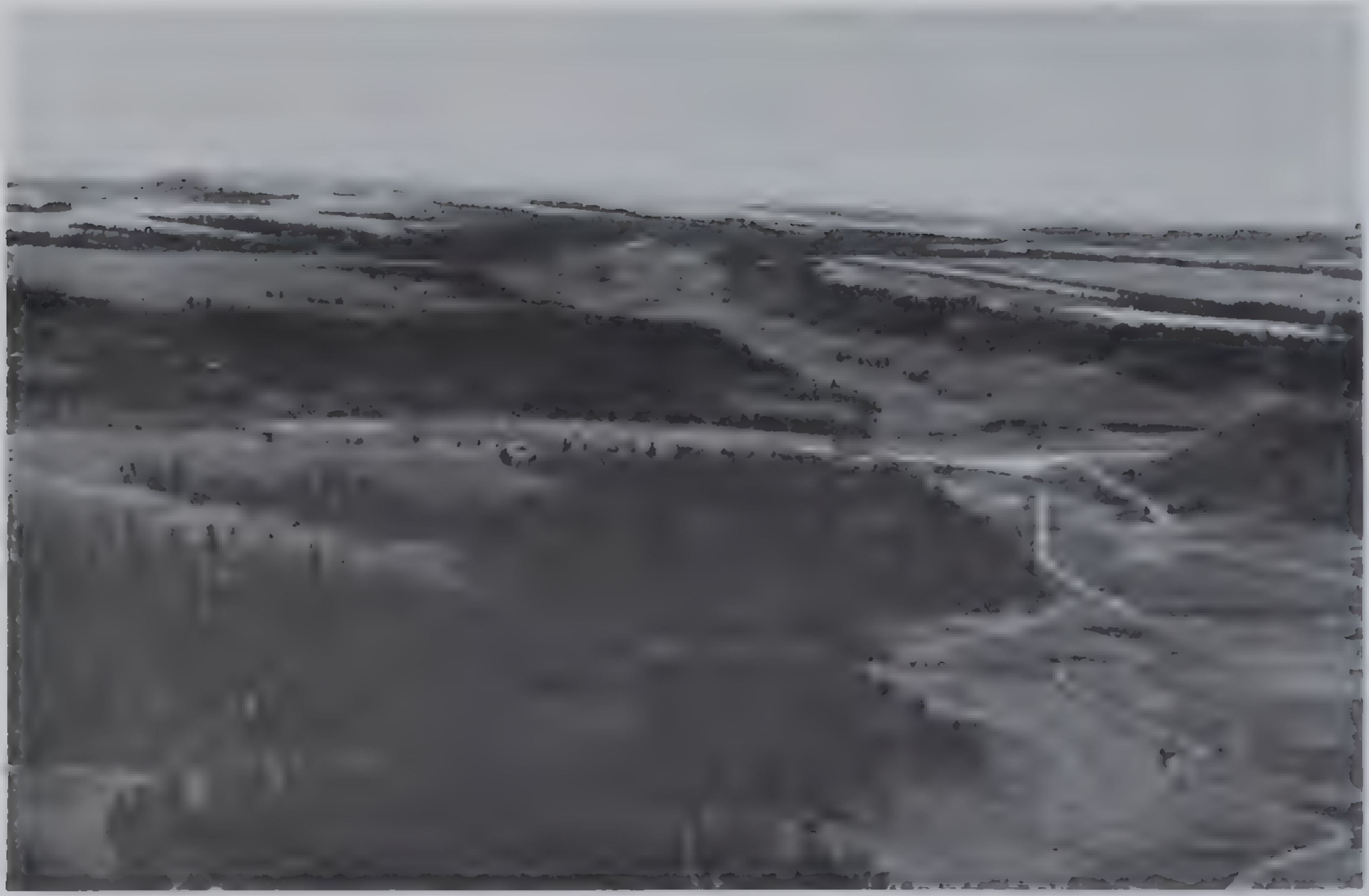
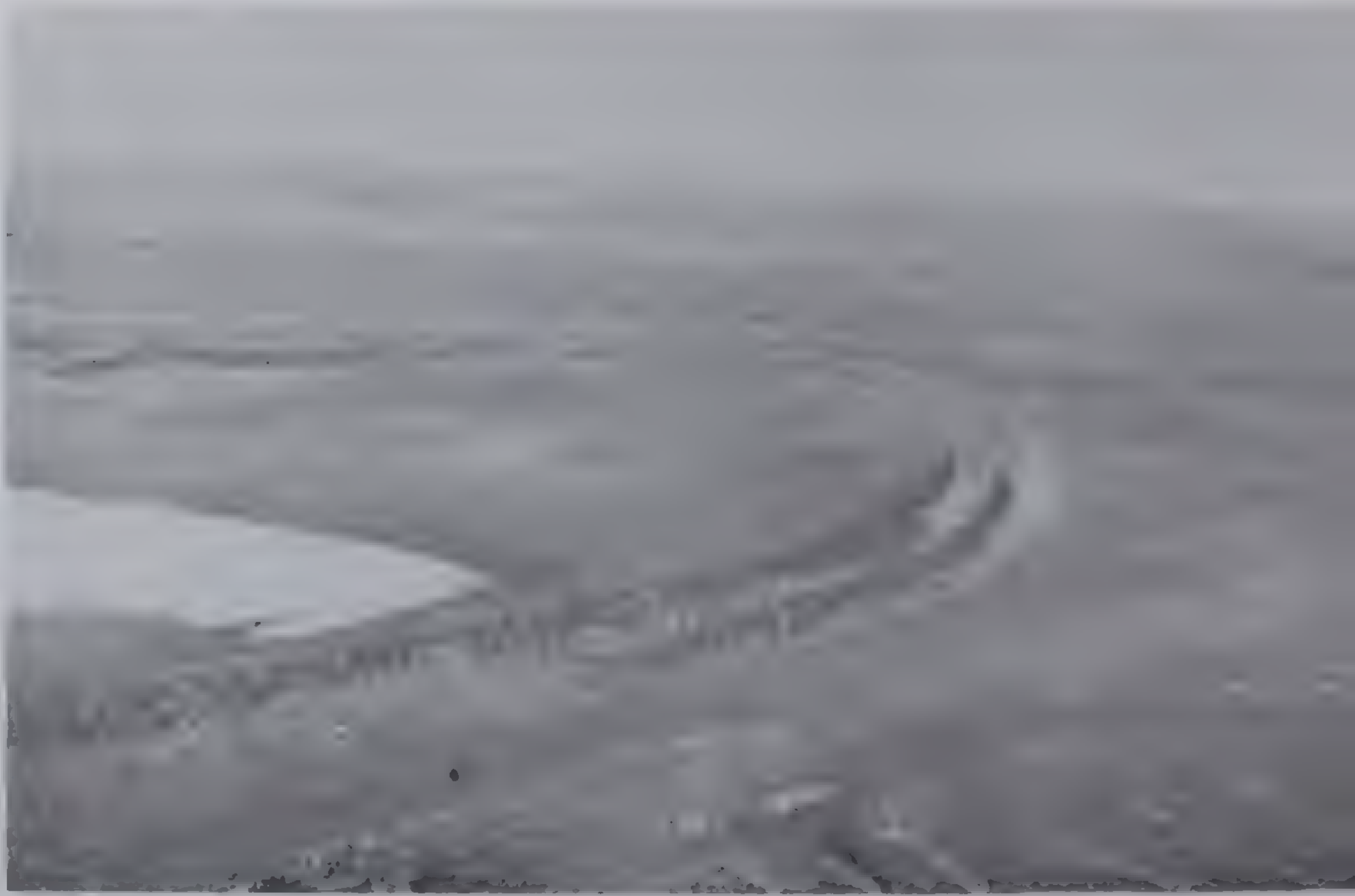


Figure 5-14

P-5. Highly dissected, interbedded sediments of varying resistance to erosion. Moderate relief with narrow, flat-topped ridges, steep valley walls, and narrow alluvial bottoms. Related to P-2, rolling plains uplands, but has greater relief.

Figure 5-15

P-6. Hogbacks formed by differential erosion of dipping beds of varying resistance to weathering and erosion. Relief low to moderate, and localized.



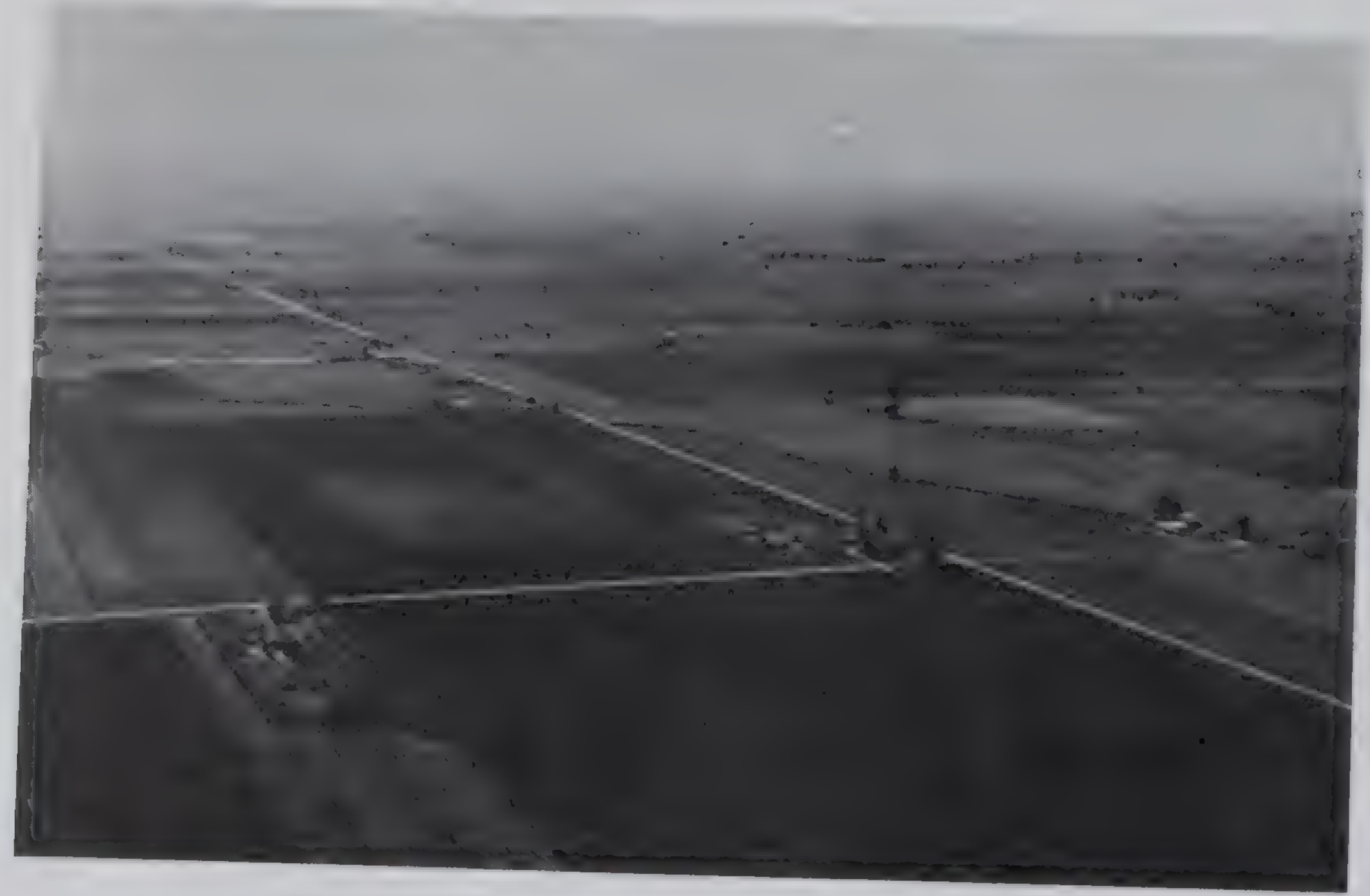


Figure 5-16

A-1. Floodplains and low terraces. Well drained; water table relatively deep.

Figure 5-17

A-2. Floodplains and low terraces with high water table, and marshes; wet areas which contain ponds and swamps.

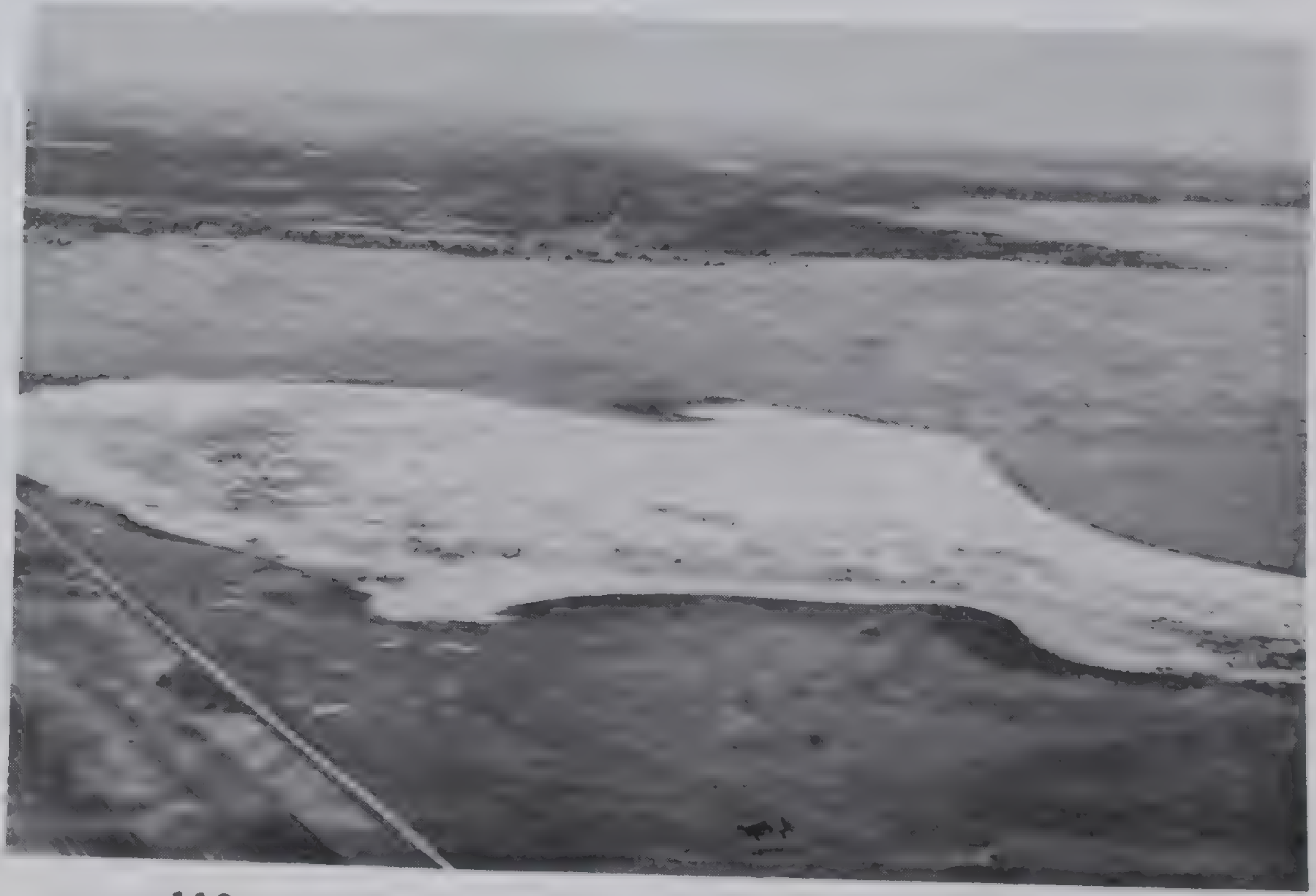


Table 5-1

MODIFIED MERCALLI INTENSITY SCALE

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motorcars.

VIII. Damage slight in specially designed structures; considerable in ordinary buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of slight and level distorted. Objects thrown upward into the air.

(From Coffman and vonHake 1973)

Magnitude (measured by the Richter scale) is a logarithmic measure of the energy released by a quake. Maximum intensity and magnitude correlate only roughly because they evaluate different properties (Table 5-2). This correlation is particularly weak when earthquakes of different depths are compared. Shocks of magnitude 5.0 or below generally do not cause great damage.

Table 5-2

MAXIMUM INTENSITY AS RELATED TO MAGNITUDE OF SHALLOW EARTHQUAKES.

MAGNITUDE (Richter Scale)	INTENSITY (Modified Mercalli Scale)
2	I - II
3	II - IV
4	IV - VI
5	VI - VII
6	VII - IX
7	IX - X
8	X - XI
8.5	XI - XII

Earthquakes are not distributed randomly in either space or time. Certain parts of the world and parts of Montana are more seismically active than others. Also, at a given location, significantly more earthquake activity may occur in one period of time than in some other equally long period.

Temporal earthquake distribution patterns in Montana before the 1860's are unknown, since no earlier records exist. Accurate instrumental records exist for an even shorter period of time. Spatial distribution patterns can be only poorly estimated from the presence of large faults and fault scarps and from some understanding of the geologic setting of Montana. The distribution of pre-1860 earthquakes showing no surface manifestations is unknown. Much of any prediction of earthquake activity through the next 50 to 100 years is based upon the events of the past century which is only a moment of geologic time.

Most known Montana earthquakes, including all the major ones, have occurred west of the plains in the northern Rocky Mountain province (Coffman and vonHake 1973). This area is within the intermountain seismic belt, a broad zone of earthquake epicenters extending from northwestern Montana through the Helena area, southward through West Yellowstone, southeastern Idaho, and central Utah to southwestern Utah (Smith and Sbar 1974). Outside of California and Nevada, this zone is the most active seismic region in the conterminous United States (Figure 5-18).

Within Montana, four areas have been particularly active since the 1860's: 1) Helena vicinity, 2) Three Forks area, 3) Flathead Lake area, and 4) Hebgen Lake area. Major shocks (intensity VII or greater) which have occurred are shown in Table 5-3.

Earthquakes seldom occur singly. Two patterns of occurrence predominate: 1) one main shock followed by numerous smaller aftershocks and 2) a series (swarm) of tremors without any one outstanding shock. The Hebgen Lake earthquake is an example of the first type. There was one main shock, not proceeded by a foreshock but with hundreds of less intense aftershocks which continued for months. On the other hand, the Helena shocks occurred as a swarm with numerous quakes happening prior to and after the strongest ones (Scott 1936 and Murphy et al. 1964).

Earthquake hazard evaluation must assess the probability of earthquake occurrence plus local responses to an earthquake. Since quakes trigger landslides, seiches, and other phenomena, these secondary effects must also be considered. Table 5-4 lists some of these potential hazards, all of which exist between Colstrip and Hot Springs. To minimize the chances of earthquake damage to the transmission system, some care must be excercised in determining its location.

Algermissen's seismic risk map (Algermissen 1969) divides the conterminous United States into four risk zones: Three of these zones occur in Montana (see Figure 5-18). The zones are described as follows:

Zone 0: No damage expected

Zone 1: Minor damage; distant earthquakes may cause damage to structures; intensities V and VI.

Zone 2: Moderate damage; intensity VII

Zone 3: Major damage; intensity VIII and greater

Although this map is general, it may be the most realistic predictive device at hand for determining the 50-to 100-year hazard. More detailed maps and predictions of earthquake occurrence within much smaller areas are less reliable. Commenting on earthquake prediction in south-

TABLE 5-3

MAJOR MONTANA EARTHQUAKES

Date	Location	Intensity (Modified Mercalli) Scale	Remarks
27 June 1925	Three Forks	VIII	Many buildings damaged, rock slide blocked Lombard RR tunnel.
12 Oct. 1935	Helena	VII	A few structures damaged.
18 Oct. 1935	Helena	VIII	Strongest of series -- many buildings damaged or destroyed including new high school two dead.
31 Oct. 1935	Helena	VIII	Two dead, additional damage to many buildings.
23 Nov. 1947	S. Madison Co.	VIII	A number of buildings damages.
31 Mar. 1952	Flathead Lake Area	VII	Wells cracked and chimneys fell.
17 Aug. 1959	Hebgen Lake	X	Strongest shock recorded in Montana; buildings destroyed, roads offset, shoreline of Hebgen Lake altered, 23 dead. Waterwells as far away as Florida affected.
1 April 1969	Flathead Lake Area	VII	Damaged chimneys, windows, and a few structures.

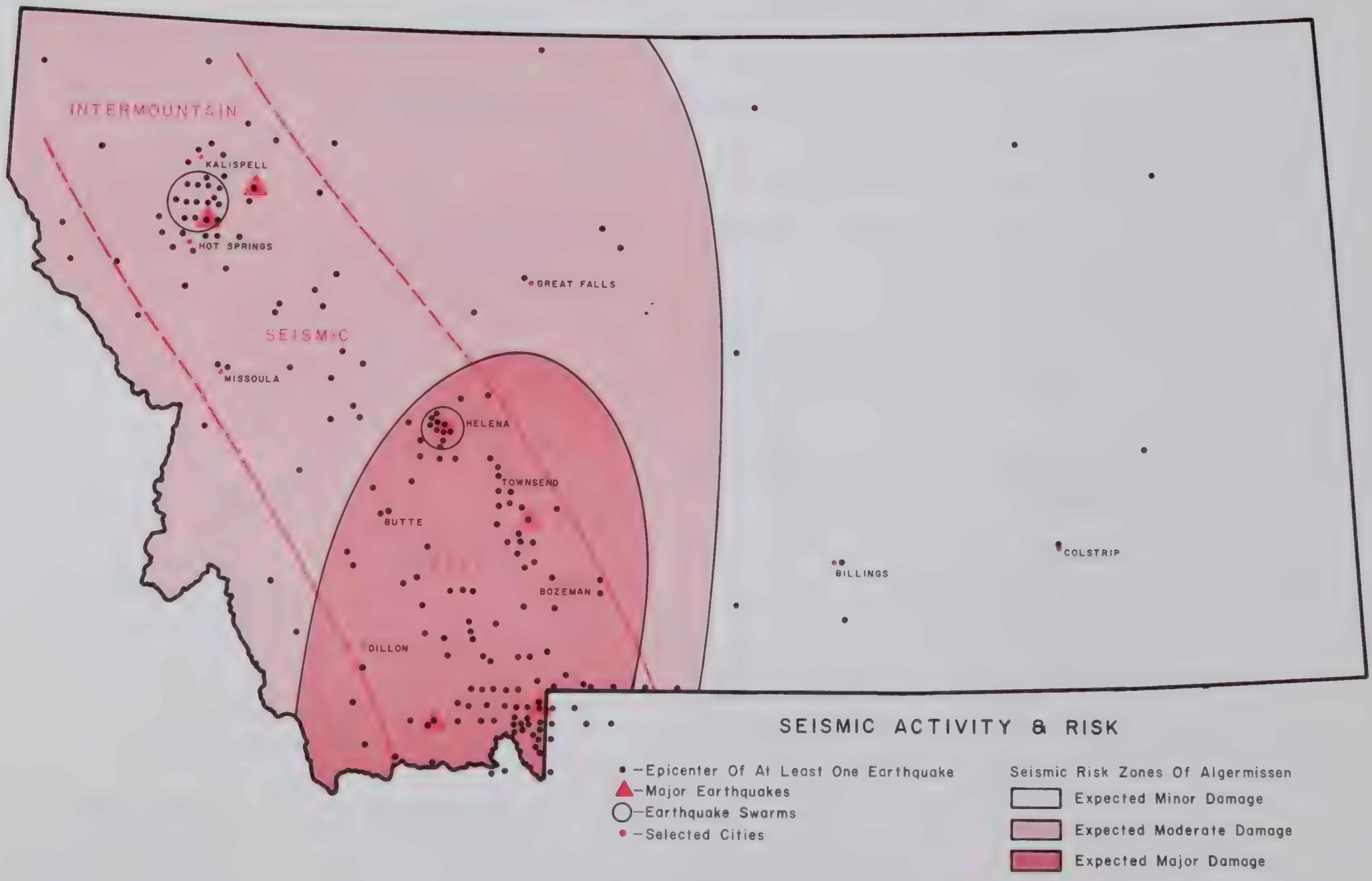

INTERMOUNTAIN
SEISMIC
KALISPELL
HOT SPRINGS
GREAT FALLS
MISSOULA
HELENA
TOWNSEND
BUTTE
BOZEMAN
DILLON
BILLINGS
COLSTRIP
SEISMIC ACTIVITY & RISK
● —Epicenter Of At Least One Earthquake
▲—Major Earthquakes
○—Earthquake Swarms
● —Selected Cities
Seismic Risk Zones Of Algermissen
☐ Expected Minor Damage
▨ Expected Moderate Damage
🟥 Expected Major Damage

FIGURE 5-18

TABLE 5-4

EARTHQUAKE DAMAGING EFFECTS

PRIMARY CAUSES	CONTRIBUTING FACTORS	DAMAGING EFFECTS	EXAMPLES
I. Earth Vibration (vertical & horizontal Accelerations)	1. None	Structures damaged	(all large earthquakes).
	2. Unconsolidated rock or man-made fill amplifying earth vibrations	Structures damaged	Greater structural damage in mined areas during Helena earthquakes of 1935.
	3. Unstable or thixotropic material	Ground breakage and mass movement	Anchorage, Alaska in 1964.
	4. Unstable slope	Landslides, mudslides	Madison canyon slide in 17 Aug 59 earthquake.
	5. Loose rocks on steep slopes	Rock fall	Closure of Lombard RR Tunnel in 1925 earthquake.
	6. Existing bodies of water	Flooding by seiche waves, tsunami, dam failure, stream blockage, etc.	Creation of Quake Lake in 17 Aug 59 earthquake, waves in Mississippi River during Missouri quakes of 1811-1812.
II. Earthsurface	7. Reactivation of surface faults	Damages roads and structures built over the break.	Roads damaged in 17 Aug 59 earthquake.

(Coffman and vonHake 1973)

western Montana, Ross and Nelson (1964) state, "Clearly the period for which accurate data are available is too short for prognostications as to future earthquake activity." The same could be said for any limited area. However, these authors go on to say:

> One may venture the suggestion that earthquakes strong enough to attract marked attention and to do some damage are to be expected to recur in or near southwestern Montana sufficiently often so that they should be taken into account in planning houses and other structures in the region.

The occurrence of several large earthquakes in this century and the widespread recent faulting in western Montana (Pardee 1950) indicates continued seismic activity for the next 50 to 100 years. Judging on the basis of seismic activity during the past century, and the occurrence of recent fault scarps, western Montana from the Helena vicinity to the Hebgen Lake area will continue to have strong earthquakes. This region is a hazardous area in which to build -- a factor to consider in selecting a route for the proposed transmission line.

The region between the Helena area and the Flathead Lake area is seismically active, but has had fewer quakes, none of which was intense.

5.1.2. Hydrology

5.1.2.1. Surface Water

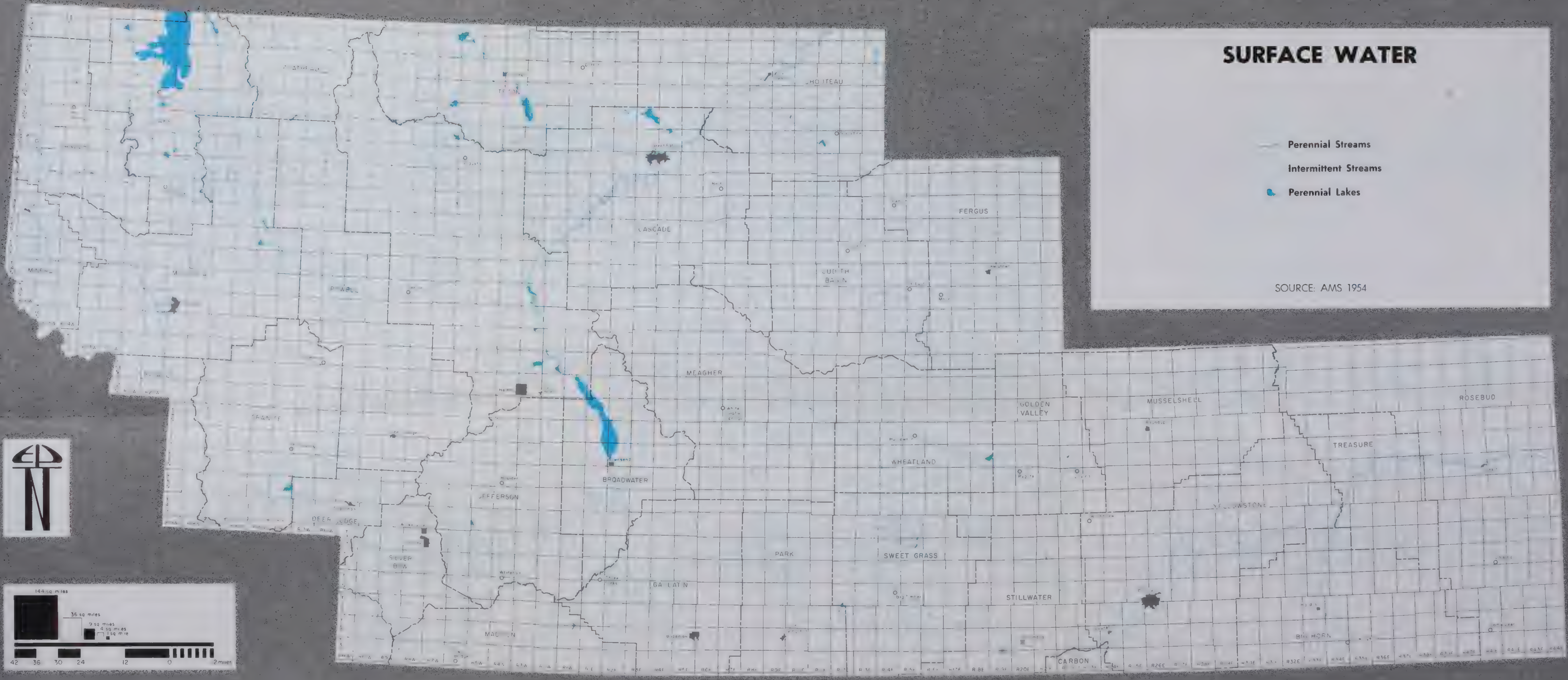
Surface waters in the study area (shown on the accompanying Surface Water Map) include streams, lakes, reservoirs, and irrigation canals. The largest streams are the Yellowstone, Bighorn, and Missouri Rivers east of the Continental Divide, and the Clark Fork and Flathead River west of the Divide. These and other major streams and their approximate locations and mean flows are indicated on Figure 5-19, Mean Discharge of Major Streams. Lakes and reservoirs include Flathead Lake, Canyon Ferry Reservoir, and many much smaller bodies of water up to several square miles in area.

Availability of surface water is strongly subject to seasonal fluctuation. Surface water is most abundant in May and June, when rains and snow melt frequently swell streams to as much as 100 times their low flow volumes. By late summer, many minor streams, as well as small stock ponds, are dry. Irrigation reservoirs are usually greatly drawn down by that time of year. Locally, some streams are severely dewatered for irrigation purposes.

A number of ephemeral lakes occupy Lake Basin and Comanche Basin, two large undrained areas northwest of Billings. These lakes are usually reduced to marshy areas by midsummer, and dry up completely by late summer.

Most of the annual runoff in streams that drain the western mountains originates as snow. (Snow-water measurements are conducted at approx-

SURFACE WATER



SOURCE: AMS 1954

imately 90 established snow survey courses and gauging stations within the study area by the U.S. Soil Conservation Service, for use in forecasting stream flow and water supply.) Reliability of water supply forecasts improves with the number of years of record from each individual measurement station, and records made over many years also reveal climatic trends. The locations of snow measurement sites are indicated on the Map of Specially Managed Areas located in Section 5.2.1.

5.1.2.2. Groundwater

Groundwater in Montana occurs in unconsolidated alluvial, colluvial, and glacial deposits, in permeable rock strata, and within fractures that occur in virtually all bedrock.

Most groundwater lies well below the ground surface, beneath the level affected by surface construction activities. The only shallow occurrences of groundwater believed to be of significance to transmission line construction are confined to unconsolidated deposits. Two situations are of concern: A high water table on flat ground (marsh, distinguished as A-2 on the Physiography Map) is important because it affects the physical properties of the material relevent to vehicular traffic and footing construction. In the other case, of mountain slopes, water that flows through a thin colluvial layer on the slopes is subject to surface diversion during excavation for access roads. This occurrence may also weaken cut slopes, promoting earth slides.

5.1.3. Soil

5.1.3.1. Parameters to be Assessed

Disturbance of the soil mantle results in varying degrees of erosion, depending on the nature and severity of the disturbance and the inherent erodability of the soil involved. Erosion, per se, is a natural process; for example, soils on flood plains are developing on material that was eroded in another location, transported by water, and deposited on the flood plain. Man's activities often disturb the dynamic equilibrium of the landscape and initiate or accelerate the natural erosional process. In evaluating this project, erosion will be considered significant when it results in lowered on-site productivity to the extent that efforts to restore a site to its pre-disturbance state are hindered or there is a high probability that eroded materials will move into surface waters, lowering off-site water quality.

Beyond assessing parameters related to impacts, there is a need to look at parameters assessing suitabilities of various landscapes for construction of a transmission line. Impacts and suitabilities may not be easily separated in actuality; insufficient attention to limitations imposed by the soil resource may result in unnecessary impacts. For example, building a road through an area subject to mass failure (usually where an erosion-resistant layer is underlain by a highly erosive layer; when exposed by road cuts, the erosive layer is removed and the resistant layer collapses under its own weight) is possible, but if construction methods used do not take cognizance of the hazard, later road bank failures will create significant sedimentation problems. Higher construction costs are also involved, as in rough, broken terrain and areas of hard, massive rock close to the surface, or where the value of other land uses precluded by transmission line construction and operation is deemed significant (critical wildlife habitat, important recreational areas, commercial timber or agriculture).

Each of these parameters is significant during transmission line construction and operation; some are important in corridor selection and others are more important in centerline selection. A list of parameters developed by Montana soil scientists (DNRC, Soil Group Workshop 1974b) were catagorized according to their significance for corridor, centerline and operation impact evaluations. These are illustrated in Table 5-5.

From this analysis certain aspects of transmission lines and certain properties of soils can be singled out for corridor selection. Access roads, staging areas, right-of-way, reclamation and maintenance are the critical aspects of the effect of transmission lines on soil properties. Soil factors of slope, compacted soil erosion hazard, revegetation potential, drainage and to a lesser extent trafficability and mass failure hazard are critically important for analysis of the aforementioned transmission line aspects. Section 6.1.3. contains further discussion and analysis of these factors.

5.1.3.2. Existing Available Data

The landform inventory technique selected, based on the Ecoclass system (U.S.F.S., Ecosystem Task Force 1973), recognized that distribution of soils is determined by factors of climate, physiography, native vegetation and the source of parent material. In a hierarchical arrangement, landscapes of a similar nature are grouped into units that become larger and more inclusive as one moves up in the system. The soils inventory for this impact statement was conducted at the sub-section level of the Ecoclass system, the level in which physiography, geology, and climate are the determining factors of classification.

> The problem is to select combinations of these various factors which yield distinctive patterns of soils which re-occur wherever the same combination of physiography, climate, geology and vegetation occur. The basis for selection of these combinations is the established relationships between soil forming processes and these factors. (Holdorf 1974).

The Colstrip-Hot Springs soils inventory is presented in map form, (see General Soils Map located in Appendix J) using USGS Area Maps (USGS 1954) of 1:250,000 scale as a base map. Detailed descriptions of the soils shown on the map are also presented in Appendix J. This was the only map series with topographic information available for the entire study area. The study area was divided into the broad physiographic units of mountains, foothills, basins, plains and floodplains. Each of these units was defined by relief, elevation, geologic structure or geo-

TABLE 5-5
Parameter Analysis

C - Corridor
CL - Centerline
O - Operation

TRANSMISSION LINE PARAMETERS / SOIL PARAMETERS	Mass Failure Hazard	Shrink/Swell Potential	Frost Heave	Drainage	Hard Massive Bedrock	Slope	Compacted Soil Erosion	Surface Erosion	Revegetation Potential	Trafficability
Right-of-way	C				C	C	C	C		
Tower Foundations	CL	CL	CL	CL	CL	CL				
Electrostatic Effects									(O)	
Electrochemical Effects									(O)	
Heat									(O)	
Access Roads	C			C	C	C	C	C	C	C
Staging Areas				C		C	C	C	C	C
Tower Erection Areas	CL			CL		CL	CL		CL	
Reclamation						C	C		C	
Maintenance						C	C	C	C	C

morphic process, and was then subdivided, using the same criteria. The additional criteria of climatic and soil properties which had been empirically determined to be significant in assessing hazards of altering land use appeared (Holdorf 1974). Climatic data came from the Montana Average Annual Precipitation Map, 1953-67 Base Period SCS 1974) (see Section 5.1.6.). Geologic information was furnished by the Geologic Map of Montana (USGS 1954) 1:500,000 scale. A slope gradient map was provided by Dr. J. M. Ashley (1973), 1:500,000 scale.

Soils information came from these sources:

Published Surveys

Yellowstone County (SCS 1972)
Judith Basin County (SCS 1967)
Beartooth RC&D (SCS 1970)

Unpublished Completed Surveys

Cascade County (SCS 1973)
Broadwater County (SCS 1974)

General Surveys

Clark Fork of the Columbia River Basin (SCS, USFS 1974)
Eastern Montana (Ashley, Mogen 1973)
Gallatin County (SCS 1968)
Jefferson County (SCS 1972)
Beaverhead County (SCS 1972)
Madison County (SCS 1972)
Park County (SCS 1972)
Meagher County (SCS 1972)
Lewis and Clark County (SCS 1972)
Soils Series of the United States, Puerto Rico and the Virgin Islands (SCS 1972)

The various offices of the SCS provided more detailed data where available.

Information was also obtained from Planning Unit Descriptions of U.S. Forest Service; much of the study area was examined on aerial photographs, 1:60,000 scale, for ground-checking of soils and physiography information (USFS 1970-72).

5.1.3.3. Data Interpretation

The soil classification system used in compiling soils data was the Seventh Approximation (Soil Survey Staff 1973). Under this system, the smallest most specific soil classification unit is the series, which can be grouped with other series of similar characteristics into the family. There are six units of classification in the system, the other four being, in order of increasing generality, subgroup, great group, suborder, and order. General interpretations can be made at the sub-group and family levels when series-level information is not available.

Mapping units were delineated based on the selected combinations of physiography, climate, geology and native vegetation. Where soils data were available within these mapping units, it was used to characterize the soil properties of that unit; the data were then extrapolated to other areas of the same mapping unit where detailed soils data were not available. Extrapolation was done only at the sub-group level, and was in every case based on reliable existing information and factors such as physiography, climate, parent matter and slope that are known to influence soil development.

Three interpretive maps resulted from this process. The Physiography Map in Section 5.1.1. is a refinement of the landscape units identified in Section 5.1.3.2. The General Soils Map in Appendix J combines available soils information for the study area and is closely related to the Physiography Map. The Sediment Risk Map in Section 6.1.3. shows impacts significant for corridor selection.

Soils in the study area can be broadly described from a physiographic standpoint as:

Soils of the Mountains

1) Soils developing in material weathered from noncalcareous consolidated rocks other than granites on steep or very steep mountain slopes with significant outcroppings of rock; in material weathered from permeable limestone bedrocks on steep or very steep mountain slopes, with areas of rock outcroppings.

2) Soils developing from material weathered from noncalcareous consolidated rocks other than granites on steep or very steep mountain slopes in higher rainfall than in material weathered from calcareous rocks of the Belt Group on steep to very steep mountain slopes; in material weathered from Boulder Batholith granites on steep to very steep mountain slopes.

3) Soils developing from clayey glacial deposits in steep mountain valleys and in material weathered from limestone bedrock on very steep mountain ridges.

4) Soils developing in loamy or clayey material weathered from soft shales and siltstones in rolling to steep mountain basins.

5) Soils developing in loamy material weathered from consolidated bedrock on very steep alpine ridges and adjacent subalpine slopes.

Soils of the Foothills

6) Soils developing in loamy material weathered from folded, consolidated sedimentary and basic igneous rocks on hilly to steep uplands and steep lower valley sideslopes.

7) Soils developing in gravelly alluvial deposits of tertiary age on nearly level to sloping high benches and alluvial fans and steep escarpments; loamy material weathered from consolidated, gently dipping sedimentary rocks on undulating to hilly plateaus and high ridges; clayey unconsolidated tertiary sediments on nearly level benches and steep escarpments; silty lacustrine deposits on nearly level benches and steep breaks.

8) Soils developing in loamy material weathered from consolidated sedimentary rocks on steep to very steep hogback ridges.

9) Soils developing on gravelly alluvial deposits of tertiary age in high precipitation on nearly level to sloping high benches and alluvial fans; in loamy or clayey material weathered from soft shales and siltstones on undulating to rolling uplands.

Soils of the Plains

10) Soils developing in sandy to clayey material weathered from sandstones and shales on nearly level benches.

11) Soils developing in clayey material weathered from clay shales on undulating to steep uplands.

12) Soils developing in loamy to clayey material weathered from shales on steep to very steep, highly dissected badlands.

13) Soils developing in clayey to loamy glacial deposits on undulating to rolling uplands.

14) Soils developing in clayey and loamy material weathered from interbedded unconsolidated and consolidated sediments on well dissected uplands, narrow level ridgetops and steep valley slopes.

15) Soils developing on clayey material weathered from interbedded steeply dipping consolidated and unconsolidated sedimentary rocks.

Soils of the Basins

16) Soils developing in stratified alluvial deposits on nearly level alluvial fans and high stream terraces; in sandy and gravelly glacial outwash deposits on nearly level outwash terraces and fans and steep terrace escarpments; in silty alluvial fans and stream terraces.

17) Soils developing in volcanic ash-capped glacial till deposits on undulating to hilly uplands.

Soils of the Alluvial Lands

18) Soils developing in highly stratified alluvial deposits on stream floodplains and low terraces.

19) Soils as in 18, but with significant areas of shallow watertables.

5.1.4. Vegetation

5.1.4.1. Existing Vegetation Types

Vegetation within the study area results from a wide diversity of topography, soils, climate, and past history of land use. Progressing from eastern Montana to western Montana the vegetation of the northern Great Plains is generally adapted to a comparatively dry climate (10-20" of rainfall per year). The mountain foothills receive more rainfall (14-30"), the northern Rocky Mountains have a still moister climate (more than 30"), and precipitation in the mountain valleys west of the Continental divide, in general, varies from 20-30" on the west slopes of the Rockies to 10-14" on the east slopes of the Bitterroot Mountains. This environmental gradient (utilizing factors of elevation, precipitation, temperature and others), in a broad system of classification, is expressed by mixed prarie grassland, foothills grassland, montane forest, boreal forest, subalpine forest, alpine, and palouse prarie grassland. The above classification serves a purpose for broad regional interpretations, but is not specific enough for determining possible impacts of a proposed transmission line. The major dominant species of a vegetation community (as shown in Appendix L2) better reflect existing vegetation on the landscape. Following is a profile of vegetation types in the study area. A list of vegetation species in the study area is located in Appendix L1.

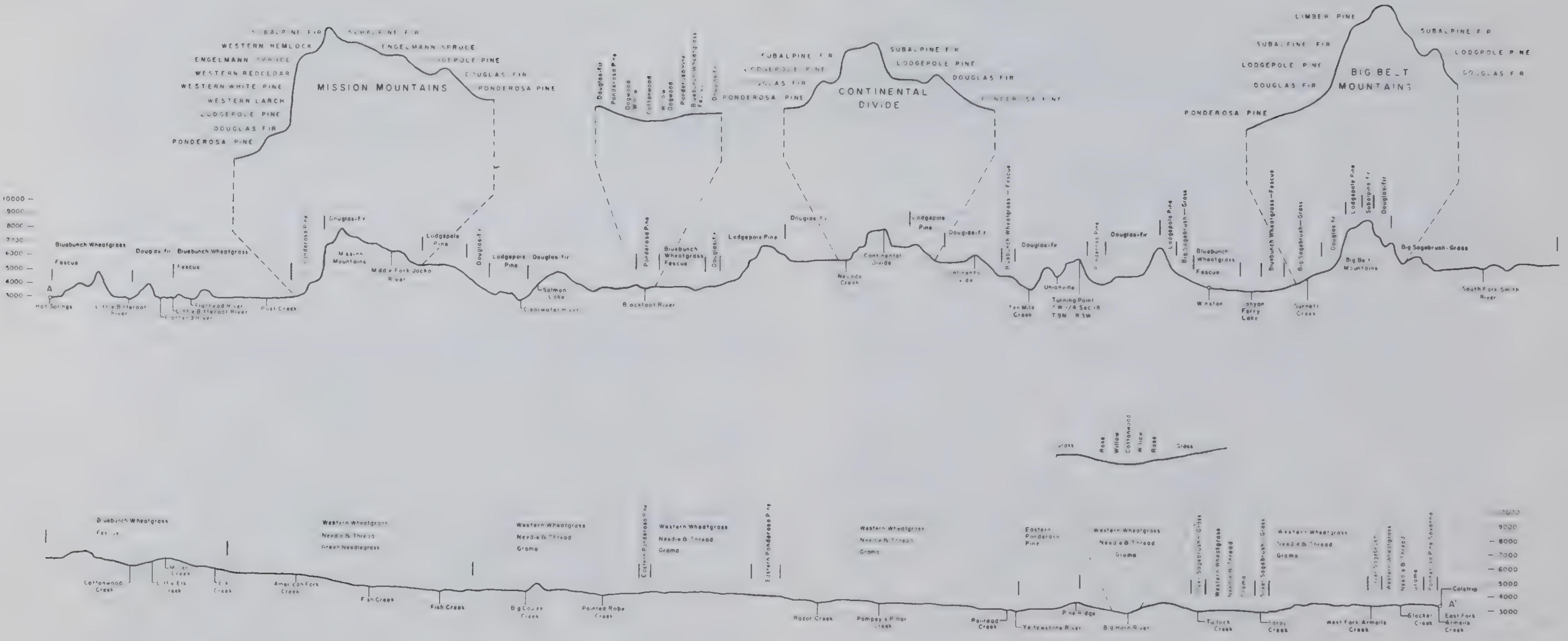
The study area has 29 vegetation types (shown on the Vegetation Types Map), classified according to life form and approximate elevation range. The environmental relationships and associated species of each type are shown in Appendix L2. However, only those that need further clarification or are "critical" in terms of impact will be discussed in the following paragraphs.

The subalpine type (from 3,500 feet to timer-line) receives considerably more precipitation (20-30") than the plains area. Lodgepole pine, subalpine fir, and Englemann spruce are common associates in this type. Whitebark pine may also occur.

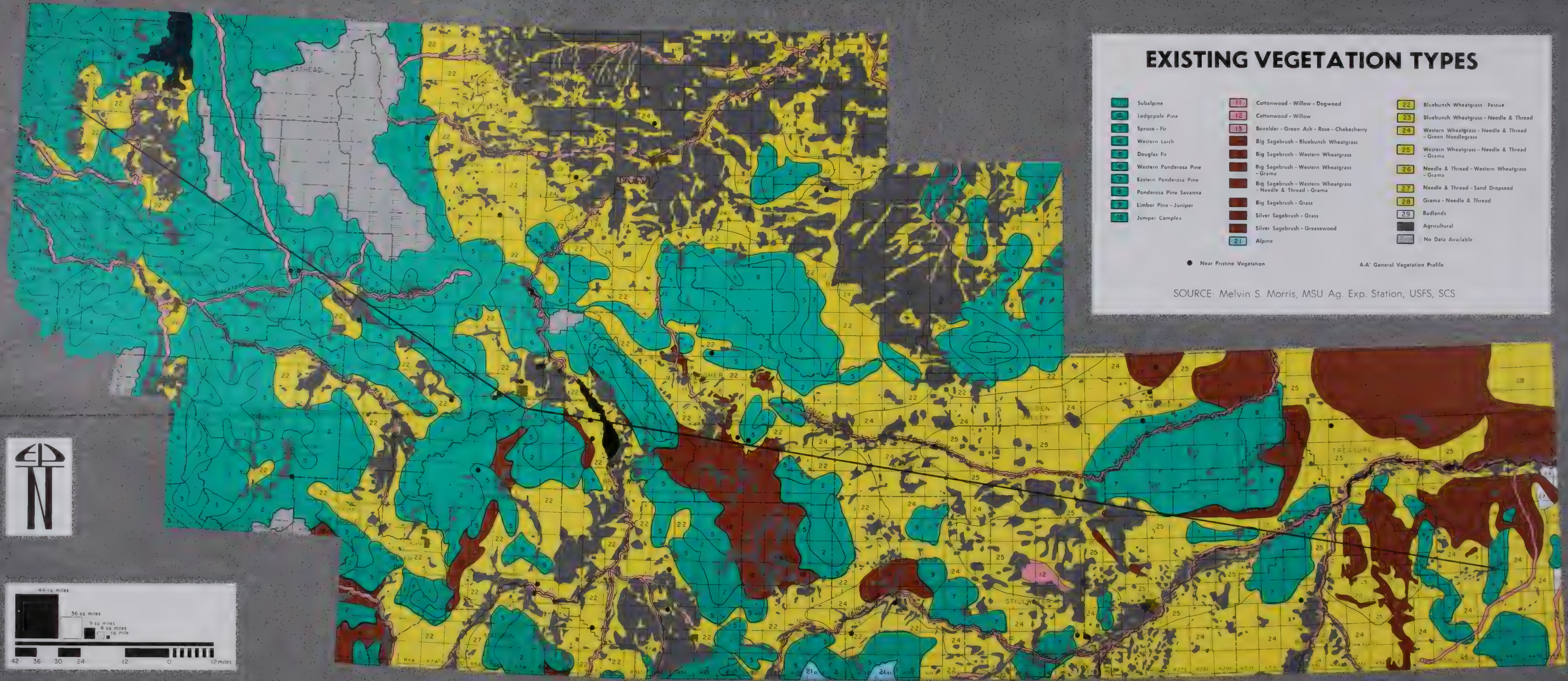
The Douglas fir type is found lower on the mountain slopes (3,000' to 7,900') than the subalpine type and is in a lower precipitation (12"°) zone. The major species of this type is Douglas fir. Other tree species include Engelmann spruce and subalpine fir in the higher levels of the zone and ponderosa pine at lower levels. Lodgepole pine and quaking aspen may be present, depending on past fire history.

The eastern ponderosa pine type occurs on the lower sites (12-18" precipitation) of the mountain slopes. Rocky mountain juniper may be associated with ponderosa pine, especially on the poorer, droughty soils of the shaley breaks. Other common associates are skunkbush sumac, bluebunch wheatgrass, Idaho fescue, sideoats grama, and little bluestem. The denser stands occur on north, east, and northeast aspects. Ponderosa pine occurs on sandy breaks.

The ponderosa pine savanna type is a mixture of scattered pine trees and grassland. This is not a true savanna, but, with respect to climate and/or fire, it is classified as such. This type



GENERAL VEGETATION PROFILE
A—A'



EXISTING VEGETATION TYPES

1 Subalpine
2 Lodgepole Pine
3 Spruce - Fir
4 Western Larch
5 Douglas Fir
6 Western Ponderosa Pine
7 Eastern Ponderosa Pine
8 Ponderosa Pine Savanna
9 Limber Pine - Juniper
10 Juniper Complex
11 Cottonwood - Willow - Dogwood
12 Cottonwood - Willow
13 Boxelder - Green Ash - Rose - Chokecherry
Big Sagebrush - Bluebunch Wheatgrass
Big Sagebrush - Western Wheatgrass
Big Sagebrush - Western Wheatgrass - Grama
Big Sagebrush - Western Wheatgrass - Needle & Thread - Grama
Big Sagebrush - Grass
Silver Sagebrush - Grass
Silver Sagebrush - Greasewood
21 Alpine
22 Bluebunch Wheatgrass Fescue
23 Bluebunch Wheatgrass - Needle & Thread
24 Western Wheatgrass - Needle & Thread - Green Needlegrass
25 Western Wheatgrass - Needle & Thread - Grama
26 Needle & Thread - Western Wheatgrass - Grama
27 Needle & Thread - Sand Dropseed
28 Grama - Needle & Thread
29 Badlands
Agricultural
No Data Available
● Near Pristine Vegetation
A-A' General Vegetation Profile
N
44 sq miles
36 sq miles
9 sq miles
4 sq miles
1 sq mile
42
36
30
24
12
0
12 miles
FLATHEAD
Blackfoot
TREASURE
STILLWATER

SOURCE: Melvin S. Morris, MSU Ag. Exp. Station, USFS, SCS

occurs in the 12-14" precipitation zone on the poorer, droughty, shaley breaks and terraces above water courses such as those near the Yellowstone River and Rosebud Creek. Rocky Mountain juniper may be present in the type. Other common associates are skunkbush sumac, western wheatgrass, bluebunch wheatgrass and blue grama. Big sagebrush may also be found in association. Ponderosa pine grows on stony or gravelly knolls, with the highest density on the north slopes. Because of the growing conditions, growth of these trees is stunted and they rarely reach commercial size (Dyksterhuis 1957).

The limber pine-juniper type is found on the drier sites in central and eastern Montana. Juniper in this type may be either horizontal juniper or Rocky Mountain juniper. This type is found at varied elevations on ridge tops and upper slopes on the poorer, shallow, rocky and gravelly, usually calcareous soils. Associated species are bunchgrasses such as bluebunch wheatgrass, Idaho fescue, and rough fescue. Some shrubs in the type are big sagebrush and silver sagebrush.

The juniper complex which contains numerous associated species is similar to the limber pine-juniper type. The complex appears on sites similar to those on which the limber pine-juniper type is found, but usually at lower elevations and on the hills rather than the ridgetops. The associated species in the complex are undifferentiated because no single species is dominant. Associated grass species are bluebunch wheatgrass, native bluegrass, rough fescue, and threadleaf sedge. Shrubs found in this type are rubber rabbitbrush, big sagebrush, silver sagebrush, and prickly pear cactus. Clubmoss occurs on the poorest sites in some quantity.

The plains grassland communities are better able to withstand drought conditions than tree species. Throughout the study area the grassland and sagebrush-grassland types occur mainly in the 12-14" annual precipitation zone.

The foothill grassland-bluebunch wheatgrass-fescue type receives slightly more annual precipitation than the other grassland types. On the bottomland areas of its distribution the annual precipitation is from 14-15" and on the upper levels, it will occur on areas receiving up to 18" or more annual precipitation. Bluebunch wheatgrass is dominant on the lower south and southwest facing slopes. It generally prevails on gravelly and sandy soils, and also appears on soils having cracks at the surface extending down into the "C" horizon of the soil profile (see glossary for profile definition), where moisture can accumulate such as on badland ridges (Morris 1973). Other species commonly associated with bluebunch wheatgrass are prairie junegrass, native bluegrass, and needle-and-thread. Under heavy grazing pressure, bluebunch is replaced by native bluegrass. Rough fescue and Idaho fescue generally occur in areas of 14" or greater annual precipitation. On the north and east slopes, rough fescue, Idaho fescue, and bluebunch wheatgrass are dominant. However, with increase in elevation, either rough or Idaho fescue dominates, and bluebunch is uncommon. The fescues grow on moderately deep soils that are coarse to medium-textured. Species commonly associated with the fescues in this type are Richardson needlegrass, timber oatgrass, and parry oatgrass.

The needle and thread-sand dropseed type occurs in the south central part of the study area. It occurs on the alluvial fan soils in the foothills of the mountains. Associated species are bluebunch wheatgrass, Indian ricegrass, prairie junegrass and clubmoss.

The mixed prarie grasslands in the study area vary in species dominance due to soil texture and structure, and give rise to four similar grassland types. The western wheatgrass-needle and thread-green needlegrass type, needle and thread-western-grama type, western wheatgrass-needle and thread-grama type, and the big sagebrush-western wheatgrass-needle and thread-grama type. Western wheatgrass is dominant in swales and when there is clay or clay loam in the "B" horizon. Green needlegrass is commonly associated with western wheatgrass and is more abundant on cracking clays (vertisol soils), especially silty clay loam, but is very sensitive to grazing pressure and is the first to drop out. Needle-and-thread grass is dominant if the "A" and "B" horizons are silty to sandy loams. Threadleaf sedge is a common associate with needle and thread. Blue grama occurs on a wide variety of soils but is more prevalent on drier sites and increases in dominance with greater grazing pressure. Big sagebrush is the leading dominant species in areas that have fairly shallow "A" horizons, warm sites (sloping to the south) and heavier grazing activity. Big sagebrush also prevails on shaley soils of the uplands.

The big sagebrush-western wheatgrass type occurs on the Tullock member of the Fort Union geologic formation. The boundary of this type should be considered very general because of incomplete geological mapping and lack of a sharp ecotone between sagebrush and grassland. Within the Tullock member there are some relatively pure grassland areas. The Tullock is not amenable to sharply delineated vegetation boundaries because it contains good sandy areas and many shale areas. Grass and shrub combinations are generally tied to sandy and loamy soils, and sagebrush-dominated vegetation is more associated with shaley (clay) soils. Even within the sagebrush areas there may be a combination of big and silver sagebrush. When using soils classification at series level for mapping vegetation boundaries, it should be noted that soil-plant relationships are not always consistent, especially if over-grazing and fire have occurred. In general, sagebrush occurs on vertisols, shale, and shale-derived materials. Soapweed, needle-and--thread, and threadleaf sedge may form moderately sized stands on sandy, rocky, or gravelly areas.

The big sagebrush-western wheatgrass-grama type was mapped using the boundaries of the Lebo member of the Fort Union formation. The Lebo can be used as a strong indicator of big sagebrush boundaries, especially in areas possessing adequate topographical relief. However, as with the Tullock member, soil-plant relationships are not always consistent. For example, the Lebo shale has some pure grasslands in it, especially on nearly level terraces (uplands). Silver sagebrush may be found on a variety of sandy areas and clay soils, depending on physiographic position of the soil, grazing, and other disturbance history. Silver sagebrush occurs in the uplands on medium- to coarse-textured soils but may occur on heavier soils in the swales and bottom-land. Blue grama grows on a variety of soil textures but generally is more abundant on flat land and southerly exposures, and is strongly associated with heavy grazing history. On clay loams and sandy loams in a 12-16" annual precipitation zone, and with moderate grazing intensity, blue grama assumes a second or third order of dominance. However, given the same conditions except with heavy grazing intensity, blue grama assumes a first order dominance (Morris 1954).

The silver sagebrush-greasewood type occurs in eastern Montana, primarily between Billings and Hardin. This type may have pure stands of either species or both combined in a co-dominant situation. In areas where the soils are more alkaline, greasewood occurs in pure stands or as the dominant species. In moister areas, silver sagebrush dominates or occurs in pure stands. Assolciated species are rose species, Nuttall saltbush, green needlegrass, saltgrass, wiregrass, alkali bluegrass, basin wildrye and wild licorice.

Big sagebrush is the leading dominant in fairly shallow "A" horizons and shaley soils. The big sagebrush-grass type occurs in western and central Montana. Because of the variability of sites, no single grass species is dominant. Associated grass species are bluebunch wheatgrass, rough fescue, green needlegrass, plains muhly, and several others of lesser importance. Forbs of some importance are locoweeds and lupine.

The badlands vegetation type is a unique one in that fairly distinct boundaries can be indicated, and vegetation cover is generally sparse. This type occurs in the eastern end of the study area, and is not distinguished by any single dominant species, but rather by communities. Each community, however, is represented by one or more dominant species as described by Brown (1971). The greasewood community is normally found on middle and lower slopes of southwest and southeast exposures. In shadscale-big sagebrush communities vegetation cover is very sparse with only a few grasses and forbs. This community exists on steeper slopes on exposed clay and silt shale beds. The big sagebrush-shadscale-bluebunch wheatgrass community is found on tallus material of sandstone fragments and clay and silt shale on southwest and southeast exposures. The big sagebrush-bluebunch wheatgrass communities are found on lower slope positions of southwest and southeast exposures. The skunkbush sumac-bluebunch wheatgrass community is generally on or just below ridge tops of west to southeast exposure. The Rocky Mountain juniper-bluebunch wheatgrass community is principally located on the southwest and northwest slopes of the deeper channels and side drainages. Knolls at the base of badlands slopes characterize the main locations of the ponderosa pine-Rocky Mountain juniper type. Pine is uniformly scattered across the knoll surface while the sloping sides are covered mainly by juniper.

This type is considerably more fragile than the others in the study area. Vegetation growing there is specialized to the extent that it is all that can grow there. The shallow, usually undeveloped soils and steep slopes are the primary limiting factors involved in species distribution of the area.

Across the study area, three riparian vegetation types occur. In the western section, the cottonwood-willow-dogwood type is found mostly along the Clark's Fork, Blackfoot, Flathead, and Bitterroot Rivers. In this type, Douglas fir is not uncommon, and sometime dominates along the river's edge. The cottonwood-willow type is found primarily along the main drainages in central and eastern Montana. This type occurs mainly on the Judith, Missouri, Musselshell, Yellowstone, and Bighorn Rivers. A third type, box elder-rose species-chokecherry, is found mainly along the Tongue River and Rosebud Creek in eastern Montana. Common associated species found in three types are rose, serviceberry, snowberry, and chokecherry.

5.1.4.2. Relict Areas

Many areas in Montana have original near-pristine vegetation (SCS 1973). Climax plant communities are recognized as being ecological standards in monitoring ecosystems. Relict areas are used for study and comparison of presently existing vegetation against the potential of the site. Should these areas be disturbed by man, unique situations of relatively stable vegetation in a state of dynamic equilibrium will be lost.

A. Method of Data Collection

Vegetation inventory for the study area was begun by compiling existing data, such as maps and any previous vegetation studies within the study area. The primary reference for all vegetation inventory is the map, "Natural Vegetation of Montana" (Morris 1964), which covers the entire state. All other mapping was done on $\frac{1}{2}$" = 1 mile base maps with 160 acres as the smallest mapping unit for vegetation types. Field checks and periodic point observations were made to correct and supplement the maps and existing data. Information noted at each observation point included:

1) Associated species lists for each type.

2) Topography (landform, elevation, aspect).

3) Soils (texture).

4) Major resource use (if evident).

5) Range condition (ocular estimate).

6) Range production (ocular estimate).

5.1.4.3. Forest Resources

The forests in Montana constitute one-quarter of the total land area. In the study area the forests on federal, state, and private land cover 40% of the total land area (See Existing Vegetation Type Map). The forest resource represents not only present and potential wood products, but also valuable watershed, wildlife, forage, and recreation areas.

For discussion purposes, the forest resource will be related to the geographical areas of western, central, and eastern Montana. Western Montana is that area west of the Continental

Divide and central Montana is that area from the Continental Divide east to Billings. Eastern Montana is that portion from Billings east to the Montana-Dakota border.

The forests in eastern Montana are generally not as extensive as those in central and western Montana. The trees are smaller in height and diameter, due to lower rainfall and more frequent drought periods. Predominant softwood species in eastern Montana are ponderosa pine and Rocky Mountain juniper. Hardwoods along the waterways are cottonwood, boxelder, and green ash.

Forests in central Montana consist of ponderosa pine, Douglas fir (the most abundant conifer in Montana), limber pine, spruce, subalpine fir, and whitebark pine. Hardwood species of cottonwood, willow, dogwood occur along the waterways, and quaking aspen may be found in patches with the softwoods.

The forests of western Montana receive considerably more precipitation (more than 60" annually, SCS 1974) than those of eastern (10 to 20") and central Montana (14 to 30"+). The softwood species in the western forests of the state are mainly ponderosa pine, western larch, Douglas fir, lodgepole pine, spruce, western white pine, and subalpine fir. Hardwoods are quaking aspen (usually occurring in association with softwoods), and paper birch and cottonwoods along waterways.

The elevatational range, and associated trees and understory species for the major forest types in all three regions, are indicated in Appendix L2.

A. Tree Size

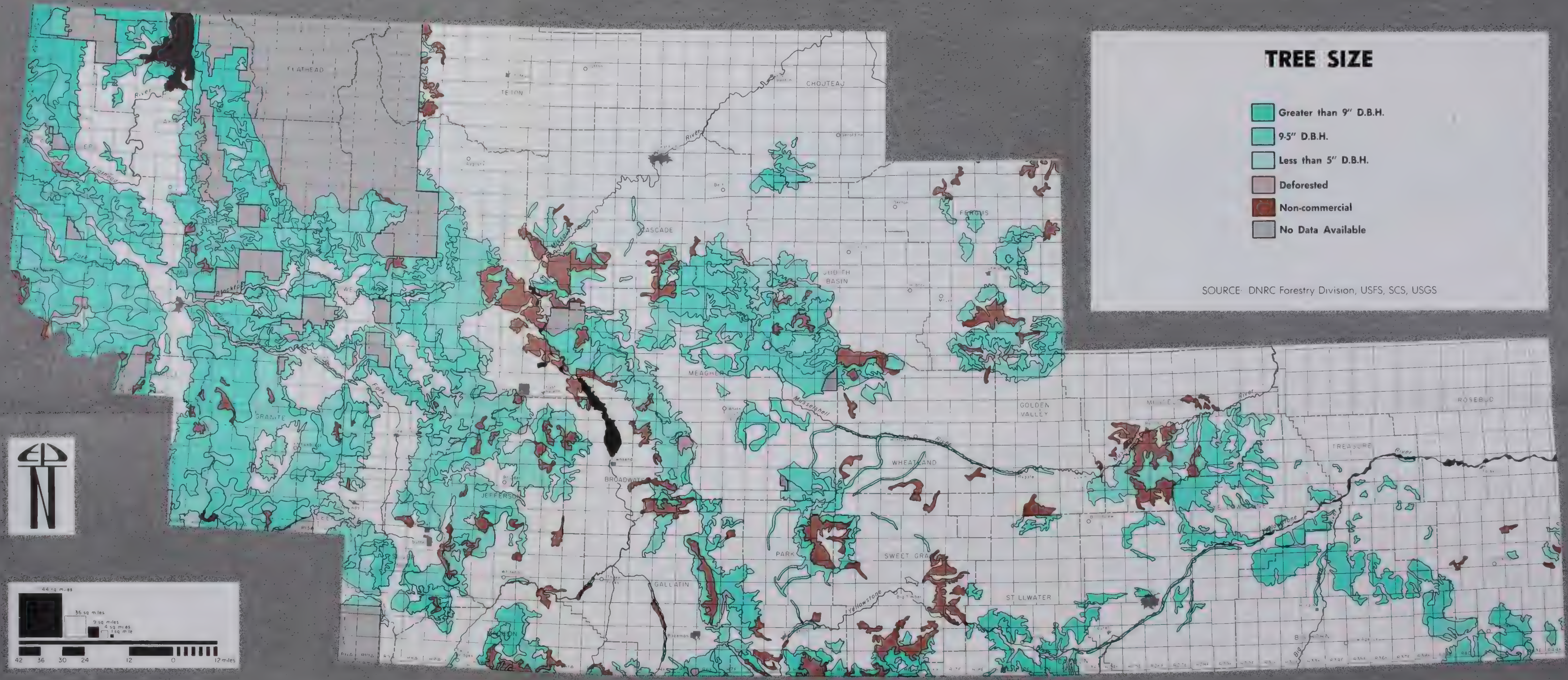
Tree size (diameter) is an important consideration for transmission line impact evaluation because it affects the cost of clearing a right-of-way, and because right-of-way clearing reduces timber volume per acre. Larger diameter trees (12" or greater) usually cost more to remove than smaller, nonmerchantable trees. However, certain methods of removal (such as hand clearing) could increase the cost.

Tree diameters are greater (average 16-18" diameter breast height (d.b.h.)) in western Montana than in central and eastern Montana (see Tree Size Map). The larger diameter softwood trees (averaging 18" d.b.h.) are usually western larch, Douglas fir, Engelmann spruce, and ponderosa pine (Pissot 1963). However, an average ponderosa pine tree in eastern Montana seldom exceeds 14".

Sawtimber class as shown on the Tree Size Map is generally considered anything over 11" d.b.h. but in the last few years, trees greater than 9" d.b.h. have been mapped as sawtimber, especially east of the Continental Divide. Most of the Region 1 national forests have at least 50% of their commercial forest acreage classified as sawtimber (See Table 5-6).

B. Forest Stocking

Forest stocking (percent of canopy coverage) is an important parameter for transmission line routing, not only from the standpoint of the impact of removing a given volume of trees, but also because of the cost of removal, and com-



SOURCE: DNRC Forestry Division, USFS, SCS, USGS

TABLE 5-6

AVERAGE BOARD FOOT TIMBER VOLUMES PER ACRE BY ACTUAL STOCKING AND SIZE FOR NATIONAL FORESTS IN THE STUDY AREA

		Sawtimber (bd. ft.)		
NATIONAL FOREST	STOCKING	WELL	MEDIUM	POOR
Beaverhead	Actual	6,503	5,202	3,901
Bitterroot	Actual	14,000	10,960	4,960
Custer	Actual	8,500	4,500	1,000
Deerlodge	Actual	10,798	8,638	6,478
Flathead	Actual	15,075	12,060	9,045
Gallatin	Actual	13,838	11,070	8,302
Helena	Actual	9,838	7,870	5,902
Lewis and Clark	Actual	10,500	7,175	2,000
Lolo	Actual	14,919	11,935	8,951

TABLE 5-6 continued

AVERAGE BOARD FOOT TIMBER VOLUMES PER ACRE BY ACTUAL STOCKING AND SIZE FOR NATIONAL FORESTS IN THE STUDY AREA

			Poles (bd. ft.)	
NATIONAL FOREST	STOCKING	WELL	MEDIUM	POOR
Beaverhead	Actual	5,430	4,334	3,258
Bitterroot	Actual	4,500	3,500	2,700
Custer	Actual	7,000	3,000	500
Deerlodge	Actual	5,480	4,392	3,304
Flathead	Actual	4,379	3,503	2,627
Gallatin	Actual	5,250	4,200	3,150
Helena	Actual	5,063	4,050	3,037
Lewis and Clark	Actual	5,400	3,960	1,200
Lolo	Actual	5,625	4,500	3,375

Source: U.S.F.S.

paring an area of high stocking to an area of low stocking. Stocking is only one consideration, however; the average size of the trees must also be considered.

Considering all tree species and size classes, the national forests are predominantly medium to well stocked. This of course varies by site, and in general stocking approaches 80 to 100% on north and east facing slopes on both sides of the divide due to cooler and moister growing conditions.

State and private forest lands are usually "stringers" coming off national forest land and their stocking rates are lower especially in eastern Montana (see Forest Stocking Map).

C. Forest Production

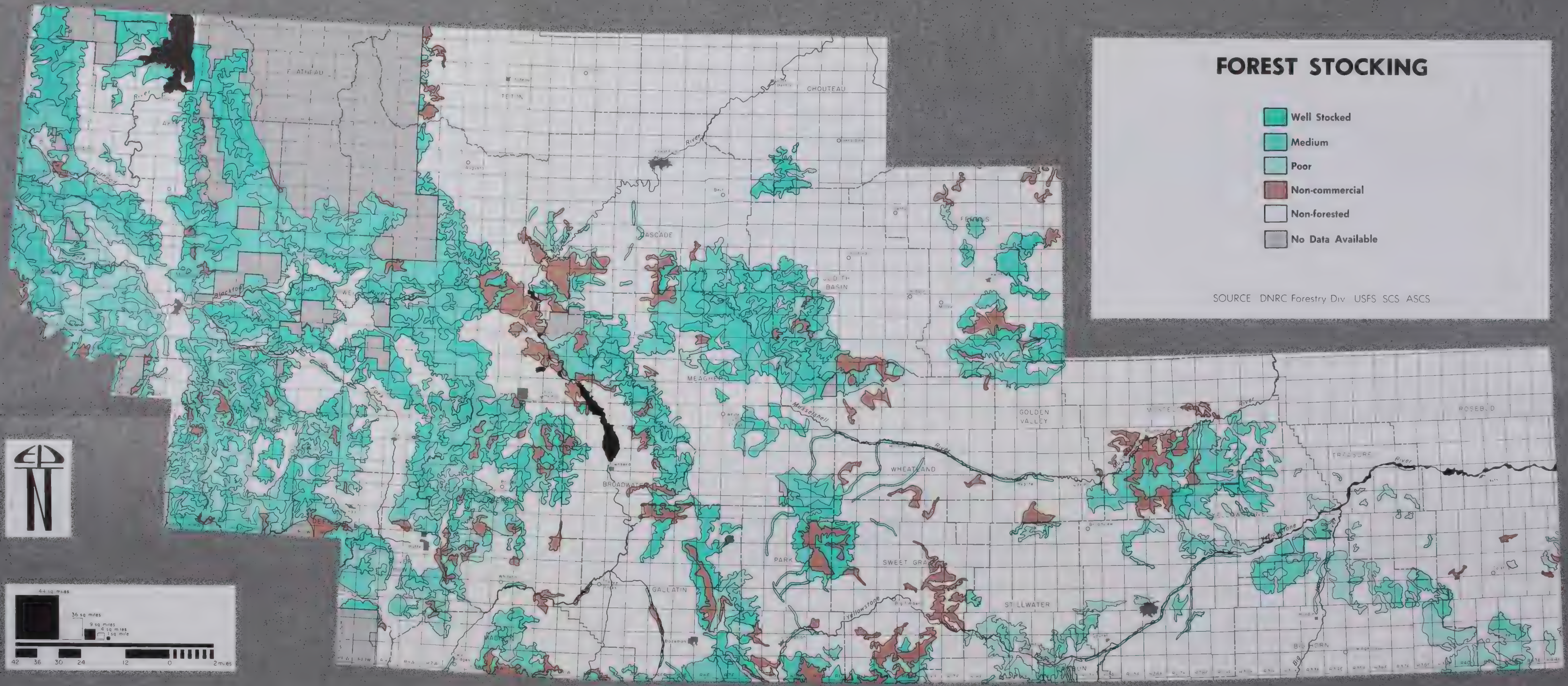
Tree size and forest stocking can be used to make rough approximations of board foot volumes per acre (bdft/acre). Besides the two parameters given above, tree volume per acre is determined by total tree height, form, age, species, locality, and site index. Diameter and height growth are products of precipitation, topography, soils, and competition with other vegetation. The sites with the highest forest volume in the study area are generally in high rainfall areas in the valleys and stream bottoms, with deep rich soils and lack of competition with other trees. The poorer sites are on ridge tops, where the soil is shallow and not as fertile. Site index is measured by the total tree height achieved in 50 or 100 years.

The potential of a site to produce merchantable timber is directly measured by site index. As indirect means of predicting site production is by considering the potential or climax species for a given site (habitat type). According to Forest Habitat Types of Montana (Pfister et al. 1974), the most productive habitat types in western Montana are the subalpine fir/queencup beadily, subalpine fir/devils club, spruce/queencup beadily and spruce/dwarf huckleberry associations. The most productive habitat types in central and eastern Montana are the subalpine fir/sweet scented bedstraw, subalpine fir/dwarf huckleberry, spruce/sweet scented bedstraw and spruce/ninebark associations.

In western Montana the most merchantable species are western larch, ponderosa pine, and Douglas fir and Engelmann spruce. Ponderosa pine is the most widely used species in eastern Montana.

Of the 38 counites in the study area, Missoula County has the largest commercial forest acreage (1,464,402 acres) including federal, state, and private ownership (Forest Sub-Committee 1971). Golden Valley County has the least commercial forest acreage (19,921 acres). Volume and commercial acreage data for the counties are given in Table 5-7. These values came from the most recent data available; the oldest was back in the 1940's (USFS 1942). Average bdft/acre values resulted from dividing the total commercial timber volume (both hardwood and softwood) by the total commercial forest acreage in each county. For volume figures for national forests see Table 5-6.

Production figures in the form of bdft/acre



FOREST STOCKING

SOURCE DNRC Forestry Div USFS SCS ASCS

Table 5-7

Sawlog Volumes and Commercial Forest Acreages for Counties in Study Area

Counties	Year of Inventory of volumes	(Hard & Softwood) Timber Volumes (Thousands bd. ft.)	Acreages of Commercial Forest land	Avge. bd. ft. / acre (Thousands)
Beaverhead	1950	2,276,123	862,997	2,637
Big Horn	1949	113,345	179,185	632
Broadwater	1950	423,233	170,777	2,478
Carbon	1949	107,615	86,793	1,239
Cascade	1948	66,084	234,323	282
Chouteau	1943	10,416	51,037	204
Deer Lodge	1950	124,049	182,897	1,000
Fergus	1943	53,579	341,040	157
Gallatin	1950	2,351,088	528,651	4,447
Golden Valley	1949	16,508	19,921	829
Granite	1942	366,900	648,600	566
Jefferson	1950	714,912	427,083	1,674
Judith Basin	1945	197,860	211,045	938
Lake	1941	1,778,000	444,900	3,996
Lewis & Clark	1950	1,818,169	824,409	2,205
Madison	1950	1,360,846	404,695	3,363

Table 5-7 (cont.)

Sawlog Volumes and Commercial Forest Acreages for Counties in Study Area

Counties	Year of Inventory of volumes	(Hard & Softwood) Timber Volumes (Thousands bd. ft.)	Acreages of Commercial Forest land	Avge. bd. ft. / acre (Thousands)
Meagher	1950	1,630,647	445,361	3,661
Mineral		1,172,100	539,400	2,172
Missoula	1942	3,490,800	1,193,800	2,924
Musselshell	1949	273,844	247,381	1,107
Park	1949	2,363,149	398,100	5,936
Petroleum	1948	5,904	22,608	260
Powell	1942	806,600	546,600	1,468
Ravalli	1943	1,767,700	554,200	3,189
Rosebud	1947	119,066	151,941	784
Sanders	1941	3,563,660	1,108,700	3,241
Silver Bow	1950	4,397,196	198,192	2218
Sweet Grass	1949	564,161	172,796	3,265
Teton	1948	201,076	189,925	1,059
Treasure	1949	19,772	24,418	810
Wheatland	1949	37,509	25,256	1,485
Yellowstone	1949	62,215	58,412	1,065

are important in determining the trade-off values of prospective transmission line corridors. High-volume areas would require greater cost for clearing, and potential forest production would be lost in the 300-foot right-of-way. Also, some timber-producing sites, particularly areas that have highly erosive shallow soils on steep slopes, would not be able to recover from clearing operations and associated road systems.

D. Forest Industries

The main products obtained from study area timber are lumber, plywood, posts, studs, poles, ties, house logs, and wood chips. Lumber is the predominant product in western Montana and central Montana. Next in importance for western Montana is plywood and paper products while studs, posts, and poles, are secondary products in central Montana (USFS 1974). Most of the timber in eastern Montana is used for studs (Pyke 1974).

The major locations for processing timber in the study area are Missoula, Bonner, Frenchtown, Seeley Lake, Lincoln, White Sulphur Springs, Belgrade, Lewistown and Roundup. Small sawmills and post-and-pole plants are located throughout the study area. Outside the study area, the important processing centers are Libby, Columbia Falls, Dillon, and Thompson Falls.

E. Forest Condition

Forest condition is a measure of the overall health of the forest, considering such factors as insect and disease and epidemics and possible air pollution damage.

Within the study area, the major damage-producing insect is the mountain pine beetle, which affects western white pine, ponderosa pine, and lodgepole pine, especially on the Crow Indian Reservation and in the Gallatin and Helena National Forests. Near-epidemic outbreaks have been reported in these areas, and the potential exists for aggravating this situation by clearing and slash piling in the summer months. Leaf-defoliating insects, except for the Douglas fir tussock moth, are not a major problem. The transmission line is not expected to cause an abnormal increase in outbreak of defoliating insects (Ciesla 1974).

Forest diseases are not reported to be in epidemic proportions in the study area, although a possible increase in root rot fungi might occur with construction of the proposed transmission line because of stumps left in the right-of-way. Air pollution damage to forests in the study area has been reported near Butte (hydrogen fluoride damage), Anaconda (SO_2) and Missoula (SO_2) (McGregor and Williams 1973). Discussion of the relationship of air pollution damage to an operating transmission line is located in Section 6.1.4.

F. Method of Data Collection

The forest stocking and tree size maps on state and private lands came from the 1960-1963 forest inventories of the counties made by the Forestry Division of the DNRC. If the county was not included in the above described inventory, stocking classes were derived from aerial photographs and diameters came from interviews with land managers and then were verified with field spot checks.

Tree size and forest stocking data on national forest land came from inventories in 1957 and 1961 that were revised in 1968 in some areas. Forest information on BIA lands came from 1971 inventories.

The forest maps do not show any changes in stand size and stocking due to growth, mortality or cut over areas since the data of inventories mentioned above.

5.1.4.4. Range Resource

The area of rangeland and timber land suitable for grazing within the study area is approximately 60% of the total land area. This resource is important to the state in many respects. Montana's largest industry, livestock production, depends on forage produced by the range to meet the ever-increasing demand for livestock products. A tremendous variety of wildlife species are supported by rangeland throughout the study area. Many recreational activities are closely associated with the range resource; it provides hunting and fishing locations, scenic beauty, and space to find solitude and quiet. In addition, the range also is a watershed and thus is closely connected to effective water conservation and management.

Each vegetation type offers its own livestock, wildlife, recreation, and watershed uses. However, in order for rangeland to supply these needs, rangeland vegetation must be in good condition, and forage production must be capable of supporting both livestock and wildlife in conjunction with the other uses of the range. Good management practices can help insure that condition and production are optimized.

Range vegetation types (grassland, sagebrush, timbered range, and broadleaf) are shown on the accompanying Range Vegetation Types Map and Appendix L2 as a broad classification of vegetation within the study area.

Within the study area there are five major geographical range types (Payne 1973):

1) Western forest and alpine rangeland

2) Intermountain grasslands and meadows

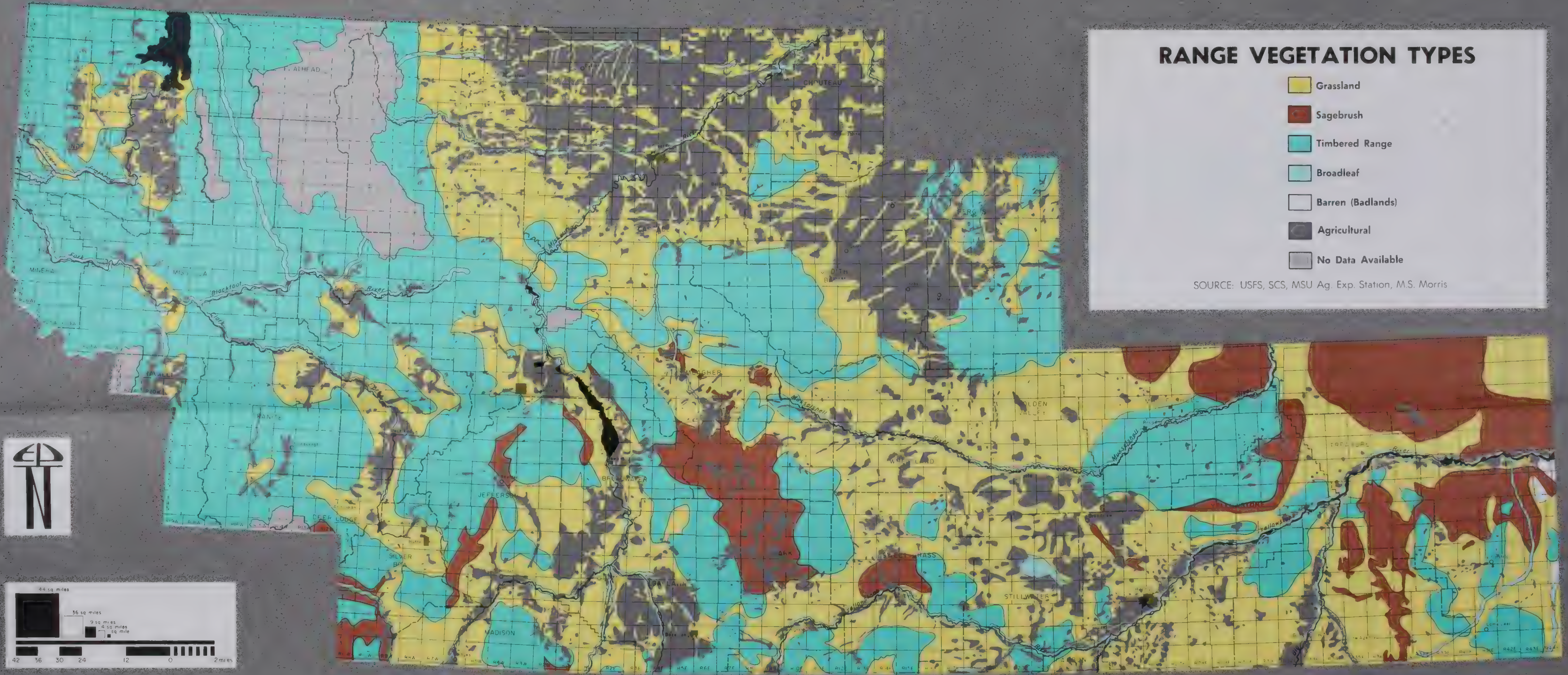
3) Foothills grassland

4) Central grassland

5) Eastern ponderosa pine type and savanna

Each geographic type contains one or more of the vegetation types in the study area that are used here in place of the individual vegetation types because they represent the best data available for range condition and production estimates.

Range condition, production, and trend are regulated by climate, soils, grazing history, and present management practices. There is a cause-and-effect relationship between these factors. Range condition and trend are primarily regulated by grazing history and management practices, although climate and soils are also important.



SOURCE: USFS, SCS, MSU Ag. Exp. Station, M.S. Morris

Range production, on the other hand, is more dependent on climate and soils; however, the other factors also have an effect. Precipitation is the aspect of climate which production is most dependent upon. Vegetation growth is limited by the frequency, duration, intensity, and season of occurrence of precipitation storms.

A. Range Condition

Range condition is determined on the basis of percent of original plant cover (climax vegetation) and the species composition making up vegetation types. Five classes of range condition—excellent, good, fair, poor, and very poor—are shown on the Range Condition Map to indicate general condition in the study area.

Approximately 50% of the rangeland in the study area is in good to excellent condition and 50% is in poor to fair condition. The study area can be further divided into the individual condition classes; however, these units still are broad averages and may contain areas which fall within any of the five classifications. Sections of the study area classified as western forest and alpine grassland types are in relatively poor condition. Intermountain grasslands which are intermixed with the forest types are in fair to good condition. Foothills grassland types, mainly located on the lower slopes of the east side of the Continental Divide, are in fair to good condition. Central grassland vegetation types are generally in good condition, and eastern ponderosa pine types are in fair to good condition.

Range condition estimates were calculated by field observations and by the use of Soil Conservation Service (SCS) criteria for determining range condition. Animal-unit month (AUM) figures from Payne (1973) were used in the determination of condition classes.

Range condition is an important parameter to use in determining possible impacts on the range resources. Range in marginal condition could conceivably be pushed to a lower condition class as a result of transmission line construction.

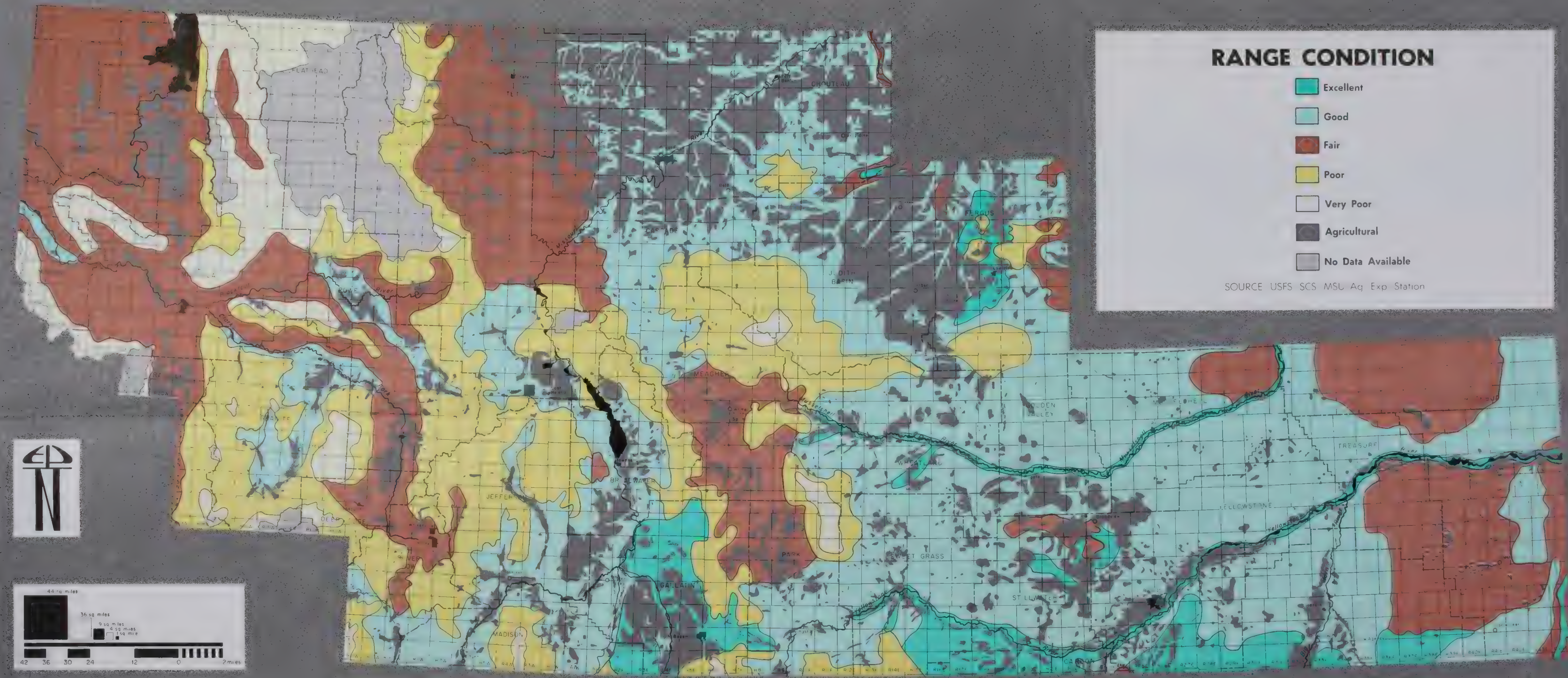
B. Range Production

Measurements of range production indicate the amount of total forage produced on a given site. Usable forage is that portion of the total forage production which can be used by both domestic livestock and wildlife without depleting the resource through overuse. Production is indicated in AUM's (see glossary).

Range production varies widely over the study area. In the western forest types, AUM's vary from approximately 32 acres per AUM, (A/AUM) in the western larch and Douglas fir forests to approximately 5.0 A/AUM in the western ponderosa pine forest, the most productive in this region.

In the intermountain grassland, production is also highly variable; however, an average production estimate is approximately 4.0 A/AUM. In the foothills grassland, production is slightly lower, around 5.0 A/AUM. In the central grasslands and eastern ponderosa pine and savanna, production averages approximately 3.0-4.0 A/AUM.

Range production estimates were taken from


RANGE CONDITION
Excellent
Good
Fair
Poor
Very Poor
Agricultural
No Data Available
SOURCE USFS SCS MSU Ag Exp Station
N
44 sq miles
36 sq miles
9 sq miles
4 sq miles
1 sq mile
42
36
30
24
12
0
2 miles
FLATHEAD
CHOUTEAU
FERGUS
JUDITH BASIN
MEAGHER
GOLDEN VALLEY
TREASURE
YELLOWSTONE
SWEET GRASS
STILLWATER
CARBON
GALLATIN
PARK
MADISON
JEFFERSON
BROADWATER

Payne (1973) and incorporated with condition class, precipitation zones, and broad vegetation units. Range production estimates for forest service land are shown on Table 5-8 by range vegetation type and condition class.

C. Range Trend

In general, range trend is an indication of the direction of change in range condition relative to the past. For example, if the range was in fair condition ten years ago, but is now in good condition, the range trend is upward.

Range trend is influenced mostly by climate, soils, and management practices. With above-normal annual precipitation over the past two decades and application of more intensive management, there has been some improvement in trend on specific ranches and allotments. However, on some heavily used pastures within the study area, the trend is downward.

5.1.4.5. Poisonous and Noxious Plants

Within the study area, several plant species have been classified as noxious or poisonous plants.

Range plants considered noxious or undesirable are those species poisonous to grazing animals, relatively unpalatable increaser species, or those species which act to suppress the growth of more desirable species through competition (Florez et al. 1972).

The most noxious plant species within the study area are knapweed, broom snakeweed, cheatgrass, Canadian thistle, field bindweed, leafy spurge, and whitetop. Of these, knapweed, leafy spurge, and whitetop are rapidly increasing in distribution throughout the study area. Many noxious weeds are introduced exotics and are highly competitive with native plant species.

Poisonous plants are generally not a problem in the study area. Most species of poisonous plants are dangerous only at certain times of the year, and then usually only some parts (e.g. leaves, roots, fruit) are poisonous. Poisonous species common to the area are death camas, cocklebur, arrowgrass, locoweed, and black greasewood. Of these species, cocklebur and arrowgrass are the most poisonous and have been responsible for some cattle losses, but they are not a large problem (BLM 1969 & 1971). Two potentially poisonous plants are chokecherry and greasewood. Chokecherry, a browse species commonly used by wildlife, is dangerous after a frost or a sudden severe drought (BLM 1967). Greasewood, also used as a browse species by wildlife and livestock, is poisonous in early spring when the alkaline content is highest in leaves.

The class of livestock (horses, cattle, sheep, or goats) grazing on an infested range is important, since not all classes are affected by the same poisonous plants. Livestock poisoning is likely to occur when animals are extremely hungry, such as after a prolonged storm. During drought periods, a lack of normally grazed, palatable species forces use of unpalatable and poisonous species that would otherwise be avoided.

TABLE 5-8

FORAGE PRODUCTION ESTIMATES (LBS/AC)

Helena National Forest

	Excellent and Good Condition	Fair Condition	Poor and Very Poor Condition
Grassland	1400	1200	800
Meadow	2000	1600	800
Timbered Range	1200	1000	600

Gallatin National Forest

	Excellent and Good Condition	Fair Condition	Poor and Very Poor Condition
Grassland	1200	800	500 or less
Meadow	2200	1200	500
Wet Meadow	3000 - 4000	--	--
Sagebrush	1200	800	500 or less
Browse	--------- negligible amount typed ---------		
Timbered Range	800 - 1000	500	100 - 300
Aspen	2200	1200	500

TABLE 5-8 (cont.)

FORAGE PRODUCTION ESTIMATES (LBS/AC)

Deerlodge National Forest

	Excellent and Good Condition	Fair Condition	Poor and Very Poor Condition
Grassland	1400*	800*	400
Meadow	1700*	900*	500
Sagebrush	1200*	600*	300
Browse	700	350	150
Timbered Range	600*	300*	150
Aspen	800	500	300

* - Based on clipping; rest based on estimates only.

Custer National Forest

	Excellent and Good Condition	Fair Condition	Poor and Very Poor Condition
Grassland	1400	1000	600
Sagebrush	1000	600	300
Timbered Range	1000	600	200

TABLE 5-8 (cont.)

FORAGE PRODUCTION ESTIMATES (LBS/AC)

Bitterroot National Forest

	Excellent and Good Condition	Fair Condition	Poor and Very Poor Condition
Grassland	725	500	275
Meadow	1200	750	450
Sagebrush	350	250	175
Browse	500	350	225
Timbered Range	250	175	125

Also because poisonous plants are often early-growing, they may be grazed before good forage becomes available if livestock are placed on the range in early spring.

5.1.5. Wildlife and Fisheries

The Colstrip-Hot Springs study area contains a wide diversity of wildlife habitat, ranging from the semi-arid steppe of the eastern plains to alpine tundra and montane forest in the western mountains. Nearly all major habitat types in Montana, and, consequently, most of Montana's wildlife species, are found in the study area.

General distribution and critical areas for important game species are shown on the Wildlife-Mammals-General Distribution, Wildlife-Mammals-Critical Areas, and Wildlife-Birds Maps. The general distribution of a species defined as its year-round geographic range, or those areas in which individuals may be found during at least part of the year. Critical areas include breeding grounds, calving grounds, wintering areas and areas of high population density.

Mammals, birds and fish found in the study area are grouped below according to their present classification by the Montana Department of Fish and Game (1973). Endangered, threatened, peripheral, and status-undetermined species are also listed. Endangered species are those determined by the Secretary of the Interior to be threatened by extinction; these are listed in the Federal Register and are protected under the Endangered Species Conservation Act of 1969. Threatened species are additional species, not listed in the Federal Register but nevertheless threatened with extinction, which are identified in the 1973 "Red Book" (U.S. Bureau of Sport Fisheries and Wildlife (USBSF&W) 1973). Peripheral species or subspecies are those which are threatened with extinction in the United States but not in their range as a whole. Status-undetermined species or subspecies are those which have been suggested as possibly threatened with extinction, but about which there is insufficient information to determine their status (USBSF&W 1973).

5.1.5.1. Mammals

A. Game Mammals

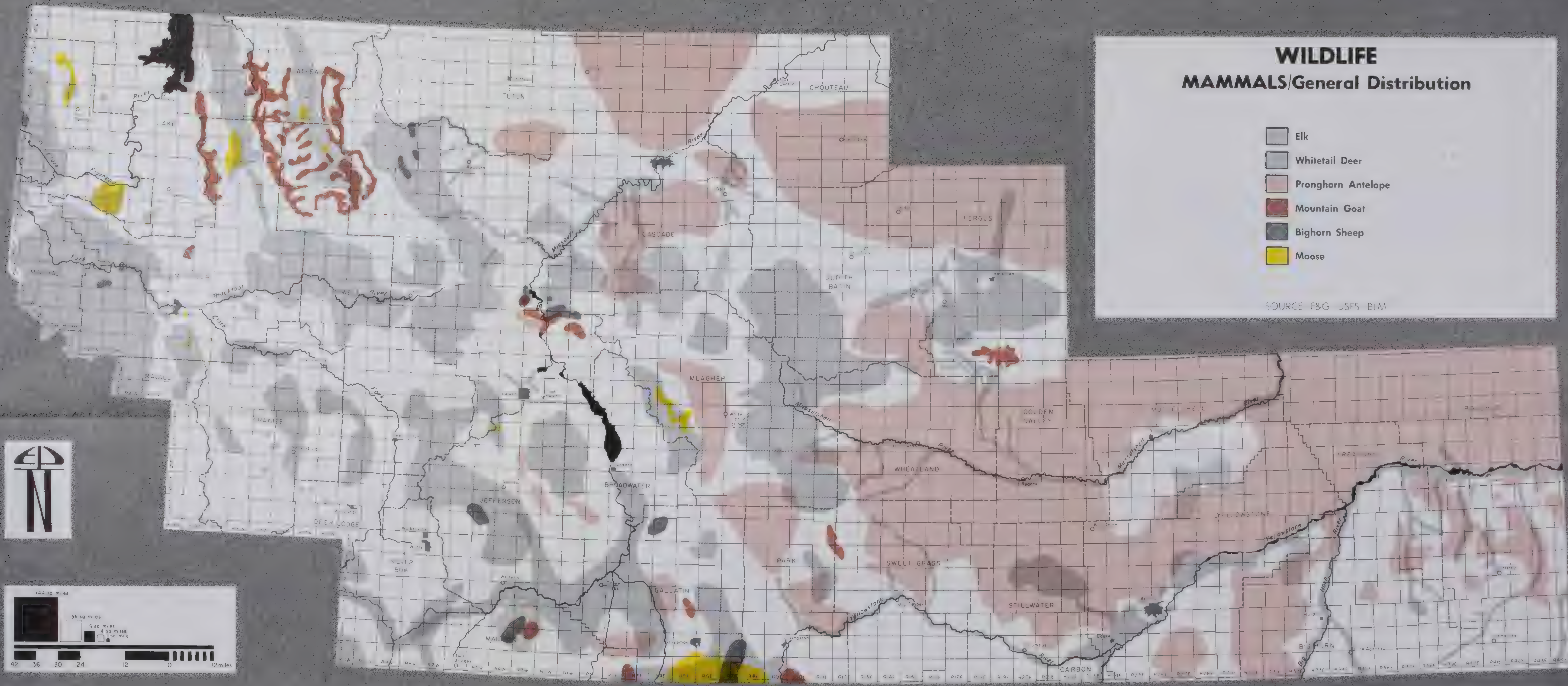
1. Elk (Cervus canadensis)

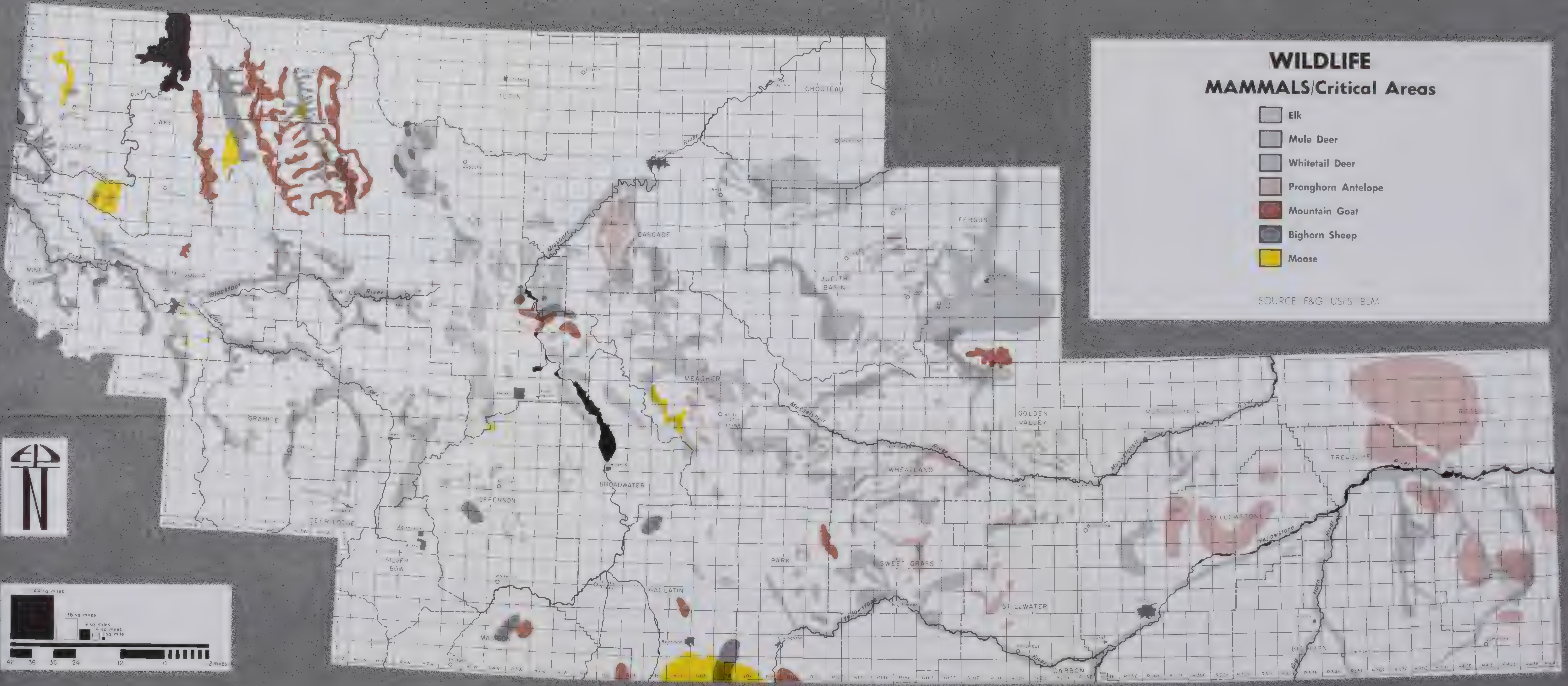
Elk are found throughout the western half of the study area. East of the divide they tend to summer at higher elevations within the various mountain ranges: Big Belt, Little Belt, Castle, Crazy, Snowy, and Bridger Mountains (Erickson 1974, Feist 1974). In winter they move to the foothills and rangelands surrounding these mountainous areas. West of the divide elk also summer at higher elevations, migrating to foothills and valley bottoms with the onset of winter. These winter ranges and calving grounds are shown on the Wildlife-Mammals-Critical Areas Map.

Elk prefer native bunchgrasses for winter food (Mussehl and Howell 1971). However, they are adaptable and will eat other grasses, sedges, forbs and browse. East of the divide, grass

WILDLIFE

MAMMALS/General Distribution





WILDLIFE
MAMMALS/Critical Areas

ranges are most often used in winter. Important plant species used on these ranges are Idaho fescue, bluebunch wheatgrass, and rough fescue (Knight 1967). In the western portions of the study area which are more heavily forested, browse winter ranges predominate. Major forage plants on these browse ranges are willow, *Ceanothus* spp., mountain maple, serviceberry, chokecherry and sedges (Mussehl and Howell 1971).

In the eastern half of the study area, elk productivity is variable. In the Castle Mountains it is only 31 calves/100 cows (Watts et al. 1972). In the Big Belts production fluctuates, with good to excellent production (50 calves/100 cows) (Watts et al. 1972) occurring on the Beartooth Game Range near Helena. West of the divide production appears good (average 47 calves/100 cows) in most areas (Janson 1973a).

2. Mule Deer (Odocoileus hemionus)

Mule deer are found throughout the study area, excluding urban areas and mountain tops; for this reason they are not included on the Wildlife-Mammals-General Distribution Map. In the more heavily forested areas of western Montana, these deer tend to be migratory, moving to valley bottoms and rangelands in winter. These winter ranges and yearlong high-density areas are included on the Wildlife-Mammals-Critical Areas Map.

Mule deer occupy most habitat types, including pine forests, spruce forests, river bottoms and badlands. Browse is the most important yearlong source of forage (Knockle 1968, Mackie 1970, Nellis 1964). Important browse species include curlleaf mountain mahogany, bitterbrush, chokecherry, serviceberry, common and creeping juniper and mountain maple, evergreen and red stem ceanothus, big sagebrush, fringed sage, silver sagebrush, skunkbush sumac, rabbitbrush, dogwood, and common snowberry. In spring and summer, forbs and the leafy portions of palatable browse plants are also eaten.

Fawn production is generally poor (38-46 fawns/100 does) in the western half of the study area (Janson 1973a, Watts et al. 1972). While production is higher in the eastern portion (45-74 fawns/100 does), it has decreased the last few years (Gordon and Coop 1973).

3. White-tailed Deer (Odocoileus virginianus)

White-tailed deer are found east of the divide primarily along the Missouri, Sun, Musselshell, Shields and Yellowstone Rivers and their major tributaries. They also occur on upland sites north of the Snowy Mountains. West of the divide white-tails may be found in the river bottoms of the Clark Fork, Blackfoot and Clearwater Rivers and in closed-canopy Douglas fir-ponderosa pine forests. The bottomlands and their associated deciduous vegetation, in addition to the browse beneath heavy conifer stands, are essential to white-tail populations throughout the year. A study in the Missouri River breaks by Allen (1968) showed western snowberry to be the white-tails' most important forage source, followed by cottonwood. Oregon grape was their most important forage source in a study by Hildebrand (1971) in the Swan valley.

On a statewide basis, white-tails consistently average 20-25% of the annual deer harvest (Mussehl and Howell 1971), and are more popular with hunters in the western half of the study area than with hunters in the eastern half.

4. Pronghorn (Antilocapra americana)

The pronghorn occurs in the eastern two-thirds of the study area. Optimum pronghorn habitat is open sagebrush-grasslands (Mussehl and Howell 1971). During summer pronghorn may utilize a diversity of habitat types, with concentrations of animals on mesic (moist) sites located in depressions and/or along creek bottoms. Wintering areas, shown on the Wildlife-Mammals-Critical Areas Map, are closely associated with silver and big sagebrush habitat types (Gordon and Coop 1973).

Sagebrush and forbs, especially fringed sage and yellow sweetclover, are essential forage items in the yearlong diet of the pronghorn (Bayless 1969, Becker 1972, Cole 1956, Wentland 1968). Shrubs are most important during winter, and forbs most important during the remainder of normal years.

Hunter harvest is declining on the western edge of the pronghorn's range (Watts et al. 1972). Here, as in all other areas of its range, the pronghorn is faced with continuing loss of sagebrush lands that are vital to its survival. In the eastern portion of the study area, although harvest has increased in recent years, productivity is now declining (Gordon and Coop 1973).

5. Moose (Alces alces)

Moose occur in the western third of the study area. High-density moose areas are shown on the Wildlife-Mammals-Critical Areas Map. These may be willow and aquatic areas, spruce-fir forests, Douglas fir forests, or deciduous forests (Knowlton 1960).

Moose are primarily browsers. At higher elevations dwarf huckleberry, willow, and subalpine fir are the most important browse items in their diet. At lower elevations Douglas fir, dogwood, serviceberry, chokecherry, and willow (where available) form the bulk of the diet (Knowlton 1960).

Moose numbers can increase 25% annually on good range (Mussehl and Howell 1971). Within the study area, it appears that most populations are stable (Watts et al. 1972, Janson 1973a) and that hunter success averages 75%.

6. Bighorn Sheep (Ovis canadensis)

Bighorn sheep occur in isolated herds in the western half of the study area. Ideal habitat for these animals is composed of rock ledges and cliffs interspersed with open slopes for feeding. These habitat types are critical because they are occupied during all seasons.

Palatable browse plants, forbs, and grasses are used for food during all seasons. Important food plants include: browse--willow, evergreen ceanothus, skunkbush sumac, chokecherry, and serviceberry; forbs--aster, arrowleaf balsamroot, lupine, milkvetch, and common salsify; and grasses--bluebunch wheatgrass, Idaho fescue, bluegrasses and great basin wildrye (Schallenberger 1966, Erickson 1972).

Productivity is variable. The Sun River herd is increasing, while sheep in the Rock Creek area have disappeared (Berwick 1968). Several areas within the study area have been stocked by transplanting with variable success (Covey and Schallenberger 1971).

7. Mountain Goat (Oreamnos americana)

Mountain goats occur in precipitous mountain areas in the western half of the study area. They often inhabit areas showing well-defined evidence of glaciation and ranging between 5,000 and 11,000 feet in elevation. Goats tend to use higher areas during summer and lower elevations during winter (Lentfer 1955).

Food habit studies have shown that grasses and grass-like plants are used yearlong and are most important in fall and winter. Forbs are most important during summer and shrubs are used during spring and winter months (Saunders 1955).

Populations appear to be stable, based on age classes of animals harvested (Janson 1973a, Weckwerth and Cross 1973).

Mountain goats were originally absent from several areas of suitable habitat within the study area. Since 1941, mountain goats have been transplanted to the Crazy, Tobacco Root, Highwood, Big Snowy, Elkhorn, Absaroka and Bridger Mountains and to the Gates of the Mountains Wilderness (Foss and Rognrud 1971).

8. Black Bear (Ursus americanus)

Black bears are found in the coniferous forests of the western third of the study area and also in several isolated mountain ranges east of the Continental Divide. They occupy a variety of forest habitats, varying from open ponderosa pine to spruce-fir forests.

Black bears are omnivorous, feeding on a variety of grasses, sedges, forbs, fruits, pine nuts and berries as well as carrion and small mammals. They overwinter in dens, which are usually located beneath large conifer or cottonwood trees at fairly low elevations. Black bears are not true hibernators; they are easily aroused while denning and are often quite active in the den (Weckwerth 1971a; Jonkel and Cowan 1971).

Black bears appear to be relatively intolerant of human habitation, logging and agricultural activities, preferring extensive undisturbed forests. They avoid clearcut logged areas until dense conifers and shrubs reappear (Jonkel and Cowan 1971).

9. Grizzly Bear (Ursus arctos horribilis)

Of an estimated 700 grizzly bears remaining in the conterminous United States, over half are found in Montana (Craighead, Varney, and Craighead 1974; USBSF&W 1973). Within the study area, grizzly bears are known to occur in the Mission Mountains, the Bob Marshall Wilderness, and in adjacent remote forested areas. The largest huntable population is found within the Bob Marshall Wilderness (Weckwerth 1971b). Although the grizzly bear is classified as a threatened mammal by the USBSF&W (1973), a relatively stable legal harvest has been maintained over the last 20 years.

Grizzly bears are omnivorous, feeding upon grasses, sedges, forbs, fruits, carrion and small mammals. Vegetation occurring along snowslide areas is an important source of early spring food. In late summer, alpine meadows are used by grizzlies feeding on vegetation and rodents. Heavily timbered areas provide fall foods such as huckleberries and pine nuts (Weckwerth 1971b).

The grizzly bear is a wilderness species, requiring extensive roadless habitat. The grizzly has not been able to adapt to human habitation and development, and where human activity accompanying logging or road construction has encroached upon grizzly habitat, the grizzly has been forced deeper into the remaining wilderness. The low reproductive potential and small population size of this species make it especially vulnerable to extinction should mortality rates exceed reproductive rates. Further habitat destruction and man-caused mortality could result in a critical population decline in this species (Craighead and Craighead 1971; Craighead, Varney, and Craighead 1974; Weckwerth 1971b).

10. Mountain Lion (Felis concolor)

Mountain lions are most common in timbered, mountainous regions of the study area; they also range into the eastern plains.

B. Furbearers

1. Marten (Martes americana)

The marten is restricted to dense stands of climax or near-climax spruce-fir forest. It is relatively rare in the study area and is listed by the USBSF&W (1973) as a status-undetermined species.

2. Fisher (Martes pennanti)

The fisher is also closely associated with climax spruce-fir forest. It was extirpated from Montana in the late 1920's; re-introductions in 1959 have resulted in small populations in the Holland Lake area of the Swan Valley and the Rock Creek drainage southeast of Missoula (Mitchell, Greer and Weckwerth 1971). It is presently classified by the USBSF&W (1971) as a status-undetermined species.

3. Mink (Mustela vison)

Mink are relatively common along waterways throughout the study area, but range further from water than beaver or muskrat.

4. Otter (Lutra canadensis)

Otters occur in the western half of the study area along major rivers, lakes and ponds.

5. Black-footed Ferret (Mustela nigripes)

Black-footed ferrets were once found in association with prairie dog towns in the eastern half of the study area, but it appears they have become extinct in Montana. The last unconfirmed sighting in Montana dates from 1970 and no confirmed sightings in Montana were obtained after 1953 (Snow 1972). The black-footed ferret is presently classified as an endangered species.

6. Beaver (Castor canadensis)

The beaver is common along waterways in the study area.

7. Muskrat (Ondatra zibethicus)

The muskrat is found along rivers and streams throughout the study area; it was the most commonly taken furbearer in Montana during the 1971-72 season.

C. Predators

1. Coyote (Canis latrans)

Coyotes are found throughout the study area; their numbers fluctuate locally as control programs change and as populations of small rodents used as food fluctuate.

2. Wolf (Canis lupus)

The Northern Rocky Mountain wolf is classified as a threatened mammal by the USBSF&W (1973). It has been eliminated from most of its former range in the study area primarily due to land development, loss of habitat, poisoning, trapping and hunting, and its inability to adapt to most of man's development activities. The last known kill of a wolf in Montana was near Lincoln in 1964 (USBSF&W 1973).

3. Wolverine (Gulo gulo)

Wolverines are rare inhabitants of timbered mountainous regions in the western third of the study area. They are listed as status-undetermined mammals by the USBSF&W (1973).

4. Long-tailed Weasel (Mustela frenata)

The long-tailed weasel is found throughout the study area.

5. Striped Skunk (Mephitis mephitis)

Striped skunks are common throughout the study area and are closely associated with agricultural areas.

6. Bobcat (Lynx rufus)

Bobcats are found throughout the study area; their populations fluctuate with their primary food source, rabbits and rodents.

D. Small Mammals

The study area supports a diverse assemblage of small mammals, including many species of rodents, insectivores, and lagomorphs, which are an important source of food for predatory mammals and raptorial birds. The distributions of many of these species are discussed by Hoffman, Wright, and Newby (1969).

E. Endangered Mammals

The only endangered mammal which may occur in the study area is the black-footed ferret (Mustela nigripes). As discussed in the furbearers section above, this animal is probably extinct in the study area.

F. Threatened Mammals

The wolf and grizzly bear, which are listed as threatened mammals by the USBSF&W (1973), have been discussed in the predators and game mammals sections respectively. The only other threatened mammal which may occur in the study area is the spotted bat (*Euderma maculatum*). The known occurrence of this species in Montana is based on a single specimen taken near Billings (Nicholson 1950).

G. Status Undetermined Mammals

The marten, fisher, and wolverine have been discussed above. Other status-undetermined mammals which may occur in the study area are the lynx (*Lynx canadensis*) and northern swift fox (*Vulpes velox*). The lynx is most common in the coniferous forests of the western third of the study area, but it is known to occur, at least sporadically, in the eastern plains. The northern swift fox is probably extinct in the study area, although it has recently been reported from Glacier County (Hoffman, Wright, and Newby 1969).

5.1.5.2. Birds

A. Upland Game Birds

1. Sharp-tailed Grouse (*Pediocetes phasianellus*)

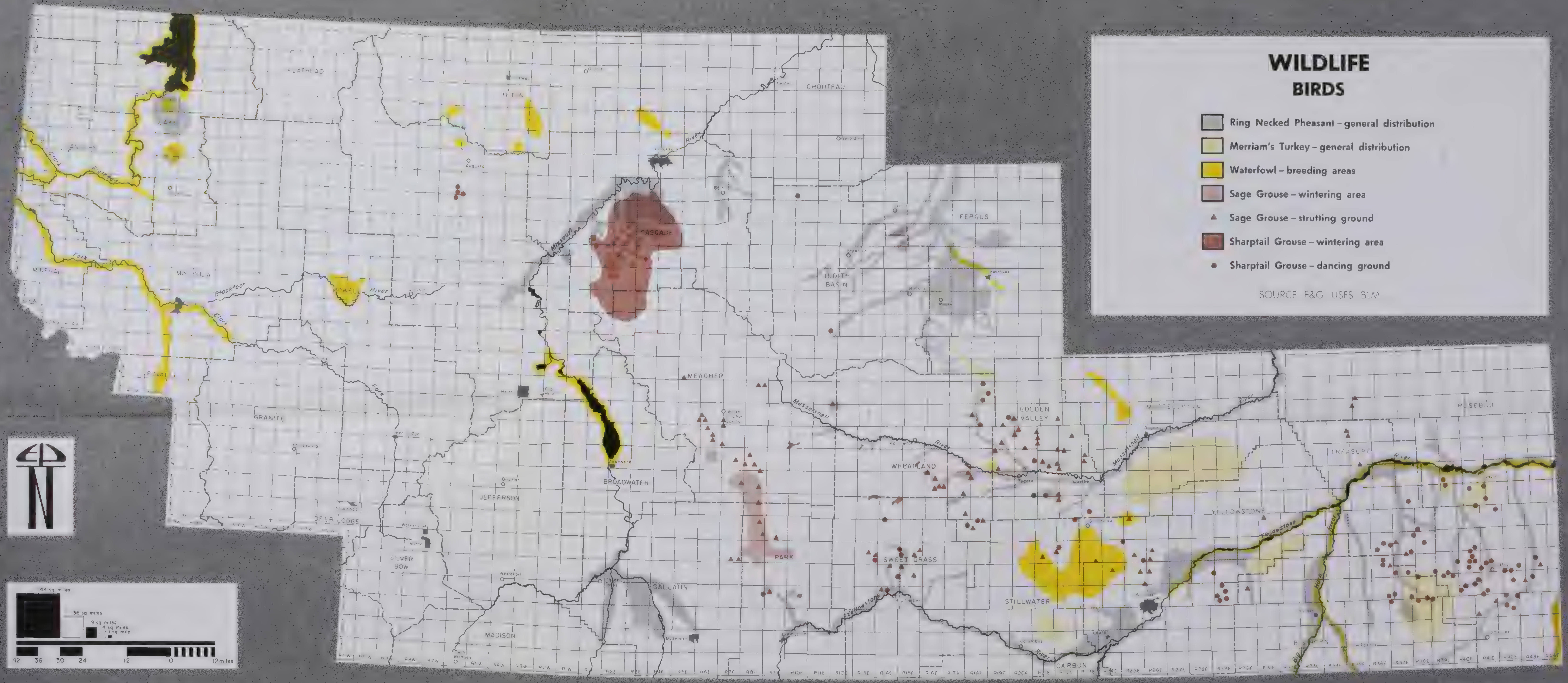
Sharp-tailed grouse occur in the eastern two-thirds of the study area, with known dancing grounds shown on the Wildlife-Birds Map. Sharptail habitat is characterized by tree-shrub--grasslands located in the upland prairie. Items essential for survival are standing grasses, dense trees and shrubs. These are needed for food, nesting activities, cover and winter survival (Mussehl and Howell 1971). Sharptail breeding population data indicate decreasing populations in the western portion of the study area (Watts et al. 1973), with stable or increasing populations occurring in the eastern portion (Compton 1973).

2. Sage Grouse (*Centrocercus urophasianus*)

Sage grouse occur in the sagebrush communities of the eastern two-thirds of the study area. Known sage grouse strutting grounds are shown on the Wildlife-Birds Map. Sage grouse are highly dependent on sagebrush, primarily big sagebrush, for their existence. It comprises almost 100% of their winter diet (Mussehl and Howell 1971). Critical wintering areas are also outlined on the Wildlife-Birds Map. Sage grouse populations seem to be either stable or decreasing in the study area (Compton 1973, Wipperman, Martinka and Constan 1973, Watts et al. 1973).

3. Ring-necked Pheasant (*Phasianus colchicus*)

The ring-necked pheasant occurs within the study area in association with irrigated bottom lands, primarily along the Yellowstone and Missouri Rivers and their major tributaries. Pheasants also occur on farmlands near Ninepipes National Wildlife Refuge south of Flathead Lake and west of Lewistown. In one study in the Yellowstone valley, cultivated grain comprised 77% of the pheasant crop volume (Hiatt 1947).


WILDLIFE
BIRDS
▨ Ring Necked Pheasant – general distribution
▨ Merriam's Turkey – general distribution
🟨 Waterfowl – breeding areas
▨ Sage Grouse – wintering area
▲ Sage Grouse – strutting ground
▨ Sharptail Grouse – wintering area
● Sharptail Grouse – dancing ground
SOURCE F&G USFS BLM
FLATHEAD
LAKE
TETON
CHOUTEAU
CASCADE
FERGUS
JUDITH BASIN
MINERAL
MISSOULA
POWELL
RAVALLI
GRANITE
DEER LODGE
SILVER BOW
JEFFERSON
BROADWATER
MEAGHER
GOLDEN VALLEY
MUSSELSHELL
WHEATLAND
SWEET GRASS
PARK
GALLATIN
MADISON
STILLWATER
CARBON
YELLOWSTONE
TREASURE
ROSEBUD
BIG HORN
Missouri River
Blackfoot River
Clark Fork
Flathead River
Musselshell River
Yellowstone River
Big Horn River
44 sq miles
36 sq miles
9 sq miles
4 sq miles
1 sq mile
42 36 30 24 12 0 12 miles
N

Pheasant populations are decreasing in the study area (Compton 1973, Watts et al. 1973).

4. Blue Grouse (Dendragapus obscurus)

Blue grouse are widespread in the douglas fir zone in the mountainous western third of the study area. The winter diet consists primarily of conifer needles, while the summer diet consists of insects, berries, and green plants (Mussehl, Schladweiler, and Weckwerth 1971). Males establish breeding territories adjacent to the forest edge. Population levels appear to be stable (Janson 1973b).

5. Ruffed Grouse (Bonasa umbellus)

Ruffed grouse inhabit dense cover in mixed forests and along stream bottoms in the mountainous portions of the study area. Their winter diet consists of the buds of deciduous trees and shrubs, and their summer diet consists of insects, berries and green plants (Mussehl, Schladweiler and Weckwerth 1971). Population levels appear to be stable (Janson 1973b).

6. Spruce Grouse (Canachites canadensis)

Spruce grouse are found in dense Engelmann spruce and lodgepole pine forests. In winter, they live primarily on conifer needles, and in summer they live on insects, berries and green plants (Mussehl, Schladweiler and Weckwerth 1971). Population levels appear to be stable (Janson 1973b).

7. White-tailed Ptarmigan (Lagopus leucurus)

The white-tailed ptarmigan is a scarce inhabitant of alpine tundra, rocky ledges, and glacial cirques; it is classified as a peripheral bird by the USBSF&W (1973). Its diet consists of new shoots, buds and reedheads of various willows, sedges, grasses, mosses and forbs (Chrest 1971).

8. Merriam's Turkey (Meleagris gallopavo merriami)

Merriam's turkeys occur primarily in the eastern half of the study area. They are most successful in forests where approximately half of the vegetative cover consists of ponderosa pine, with the remaining components comprised of grasses, deciduous trees, and shrubs occurring in scattered small openings and stream courses throughout the forest. Reports indicate that scattered small groups persist in the foothills of the Bitterroot valley and in the Clark Fork valley between Tarkio and St. Regis (Janson 1973b). Some birds have also been observed on Lynch Creek near Plains (Cross 1974). Turkey distribution is shown on the Wildlife-Birds Map.

9. Gray Partridge (Perdix perdix)

Gray partridge are scattered throughout the eastern two-thirds of the study area, inhabiting primarily croplands and grasslands. Their populations appear stable (Compton 1973).

10. Chukar Partridge (Alectoris graeca)

Chukar partridge are found in isolated patches in the study area where sagebrush-juniper or sagebrush-bitterbrush interspersed with cheatgrass and bunchgrasses occur (Mussehl and Howell 1971). These birds appear to have reached their distributional limit in the state.

B. Waterfowl

Several key waterfowl breeding and wintering areas (Wildlife-Birds Map) occur within the study area. The Flathead, Clark Fork, Jocko, Yellowstone, and Bighorn Rivers are heavily used by wintering ducks of many species. Ducks and geese also nest along these rivers. Key duck breeding areas include the flats from Big Lake to Acton, Broadview, and Hay Basin, and the lake systems around Browns and Freezeout Lakes.

Other important breeding, stopover, and wintering areas include Pablo and Ninepipes National Wildlife Refuge, Lake Helena and Canyon Ferry Reservoir.

Important waterfowl corridors cross western Montana. Whistling swans (Olor columbianus) pass from Freezeout Lake south into Idaho along a broad corridor east of the Continental Divide. Snow geese (Chen hyperborea) stop over at Freezeout Lake, then pass west out of the state along a broad corridor.

In eastern Montana, both still and running water are heavily used by migrating waterfowl.

The Montana Department of Fish and Game has plans for flooding the area south of the Comanche Basin (the Calamity Jane project) in an effort to increase waterfowl breeding habitat (Fliger 1974).

C. Endangered Birds

1. American Peregrine Falcon (Falco peregrinus anatum)

Although this species is not known to breed in the study area, a few eyries, active within the last five years, are present (Sumner 1973). Occasional birds can be expected to occur throughout the study area.

2. Whooping Crane (Grus americana)

Although the whooping crane neither breeds nor winters in Montana, occasional individuals may pass over the study area during migration.

D. Threatened Birds

The prairie falcon (Falco mexicanus) occurs in plains and valleys in the study area; it has disappeared from many locations within its overall range.

E. Peripheral Birds

The white-tailed ptarmigan has been discussed in the game bird section above.

F. Status Undetermined Birds

Birds in this category which are known to occur in the study area include the ferruginous hawk (Buteo regalis), American osprey (Pandion haliaetus carolinensis), Columbian sharp-tailed grouse (Pediocetes phasianellus columbianus), Mountain plover (Eupoda montana), northern longbilled curlew (*Numenius americanus parvus*), and the western burrowing owl (*Speotyto cunicularia hypugaea*).

5.1.5.3. Fisheries

A. Game Fish

The study area encompasses some of the finest "cold water" fisheries in the country, including some nationally famous trout streams designated as blue ribbon streams by the Montana Fish and Game Commission. The fisheries of the Yellowstone River have been discussed in Volume 3a, Section 10.1.9. of this report.

East of the Divide in the Smith River drainage, four species of trout—cutthroat (*Salmo clarki*), brook (*Salvelinus fontinalis*), rainbow (*Salmo gairdneri*) and brown (*Salmo trutta*)--are widely distributed. In addition, mountain whitefish (*Prosopium williamsoni*) are abundant in this drainage (Wipperman et al. 1973). The Missouri River system upstream from Great Falls has good populations of rainbow and brown trout. The Musselshell River upstream from Careless Creek also has good populations of brown trout (Coop 1974).

Five species of trout including cutthroat, brook, rainbow, brown, and Dolly Varden (*Salvelinus malma*) occur west of the Divide (Marcoux 1974). This would include the westslope cutthroat trout in certain waters. Kokanee salmon (*Oncorhynchus nerka kennerlyi*) are also found in some areas. The Blackfoot River drainage has good populations of brown, rainbow, cutthroat and Dolly Varden trout. Brook trout also occur in some tributaries of this river system. Individual concentrations of species may vary in any tributary. The Clearwater River has brown trout and kokanee salmon between Salmon and Seeley Lakes. The Swan River and its tributaries contain good populations of Dolly Varden, westslope cutthroat, and brook trout (Domrose 1974). The South Fork of the Flathead and its tributaries have moderate trout populations with sizable numbers of westslope cutthroat. The Jocko River near the Divide also contains westslope cutthroat. The Clark Fork River has good populations of brown, rainbow, and cutthroat trout.

B. Threatened Fish

The artic grayling (*Thymallus arcticus*), a cold-water stream fish, was once common in the Missouri River drainage above Great Falls. Today, relict and transplanted populations exist in only a few lakes and streams within the study area. The decline in numbers of this species has been due in part to the change in habitat resulting from logging, mining, and overgrazing, as well as competition from other species (Brown 1971, USBSF&W 1973).

C. Status Undetermined Fish

Fish in this category which are known to occur in the study area include the westslope cutthroat trout mentioned above and the pallid sturgeon (*Scaphirhynchus albus*), which has been reported from the Missouri and Yellowstone Rivers in the study area.

5.1.6. Meteorology

The climate in the study area varies significantly from its western to its eastern boundaries, due primarily to the Rocky Mountains, which occupy approximately the western third of the study area. The mountains affect the variation of climate by acting as a barrier to low-level atmospheric flow.

West of the Continental Divide climate is influenced by the cool, moist air masses originating over the Northern Pacific Ocean. When moist air flows into the study area from the west, it is forced to rise to cross the mountains. As the air rises, it cools, causing some of its moisture to condense and often form precipitation. After crossing the Continental Divide, the air begins to sink and warm, a process which tends to inhibit precipitation. The mountain barrier therefore maximizes the importance of Pacific moisture as a precipitation source west of the Divide while reducing its importance for the plains area east of the Divide.

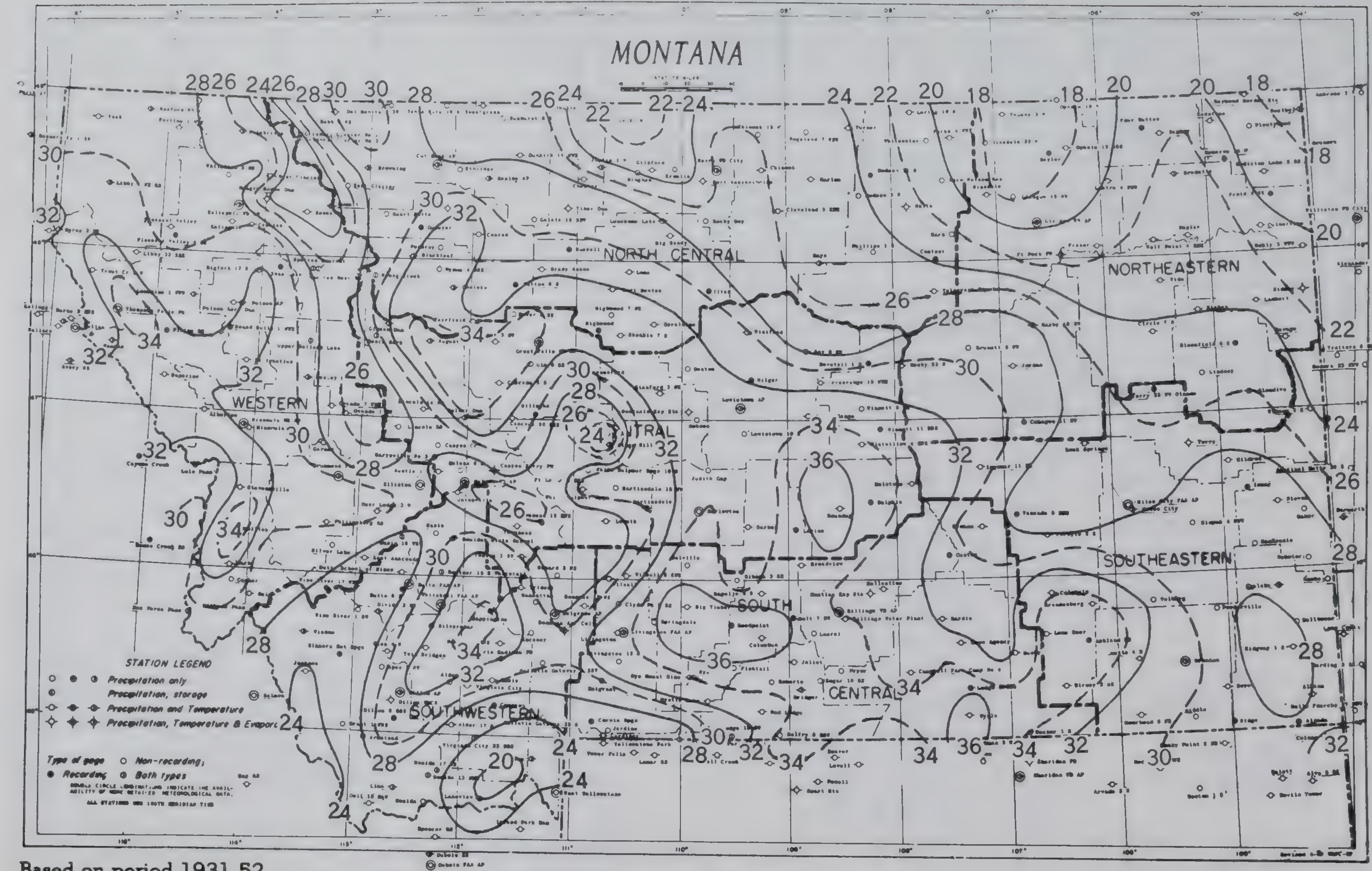
The impact of both the cold, dry air originating in the northern polar regions and the warm, moist air from the Gulf of Mexico is also limited by the mountains. These two air masses generally enter Montana east of the Divide, and the mountain barrier tends to inhibit their penetration to the western regions of the study area.

Thus the climate of the western regions of the study area will generally include milder winters, cooler summers, a more even annual distribution of precipitation, higher humidity, more cloudiness in all seasons, and lighter winds than that of the eastern plains.

Winters throughout the study area are usually cold, as is evident from Figures 5-20 and 5-21, which are U.S. Weather Service maps of mean maximum and mean minimum temperatures in January, the coldest month of the year. The coldest periods, during which temperatures can fall well below zero, are associated with intrusions of cold polar air. In localized areas temperatures of -50°F and lower can result from the combination of the cold waves and radiative cooling. These cold waves cover the eastern portion of the study area fewer times per winter than the average of 6 to 12 times reported for northeastern Montana. The entire study area will be covered an average of only one or two times per winter (U.S. Dept. of Commerce 1971). The cold outbreaks normally do not last for extended periods, and end abruptly due to the onset of warmer west or southwest winds. The warmer winds can be either winds of warmer Pacific origin (U.S. Dept. of Commerce 1960 and U.S. Dept. of Commerce 1972a), or, in those regions east of the Divide, the warm downslope wind, the chinook, (U.S. Dept. of Commerce 1971, U.S. Dept. of Commerce 1972a, and U.S. Dept. of Commerce 1972b). The coldest temperature recorded in the study area (and the continental United States, excluding Alaska) as of 1970 was -70°F which occurred on January 20, 1954 at Rodgers Pass, some 40 miles northeast of Helena (U.S. Dept. of Commerce, 1971).

Summers in the study area are warm, with the warmest temperatures generally occurring in the eastern plains. Record high temperatures in the

Mean Maximum Temperature (°F.), January



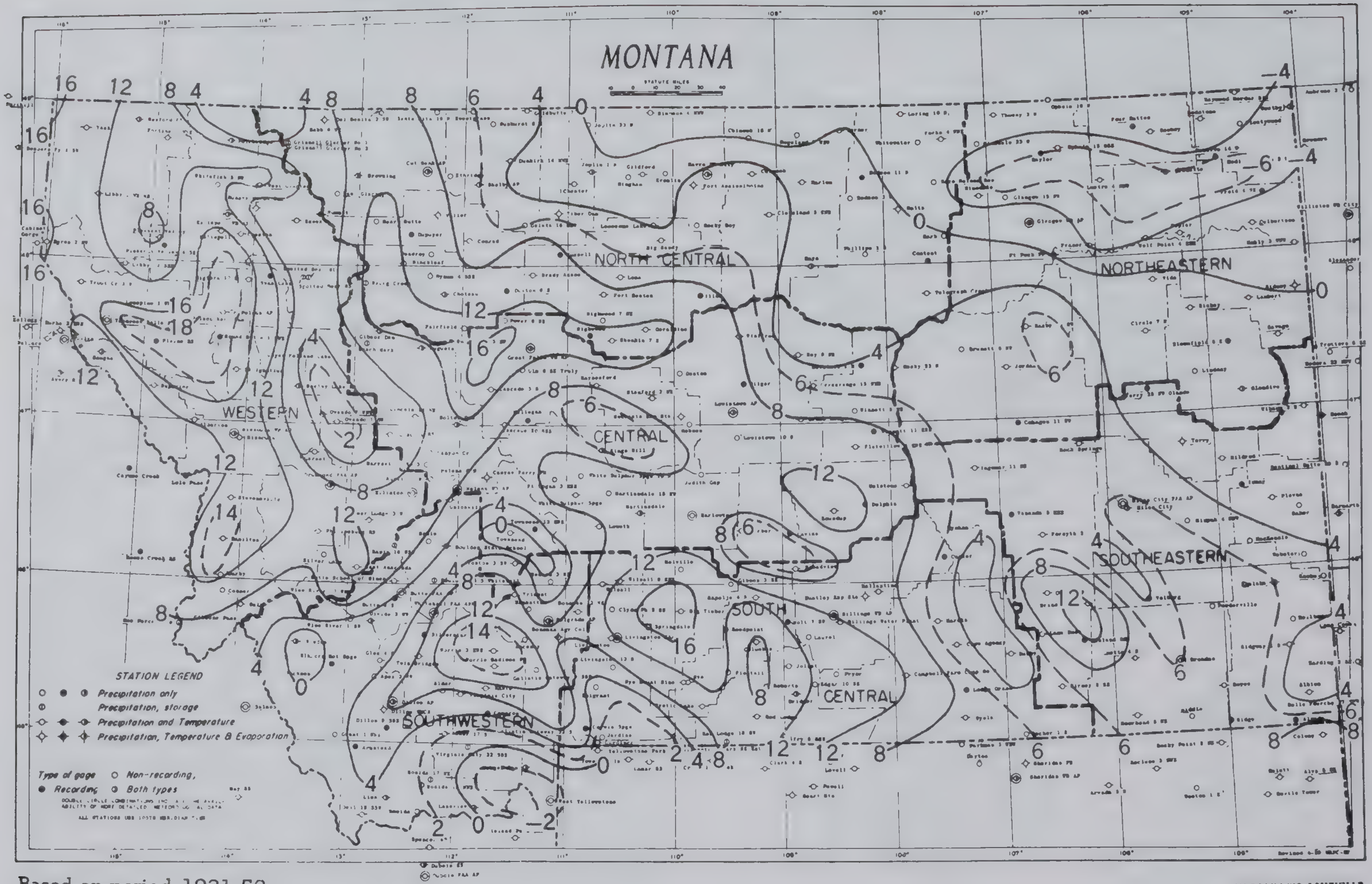
Based on period 1931-52

USCOMM-WB-ASHEVILLE

Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas.

Figure 5-20

Mean Minimum Temperature (°F.), January



Based on period 1931-52

USCOMM-WB ASHEVILLE

Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas.

Figure 5-21

Forsyth-Colstrip region are 110°F or higher (U.S. Dept. of Commerce 1965). Temperatures exceeding 100°F have also been recorded west of the Divide, but in the west hot spells are shorter and less frequent than in the eastern plains (U.S. Dept. of Commerce 1971). Figures 5-22 and 5-23 are U.S. Weather Service maps of mean maximum and mean minimum temperatures for July, the warmest month of the year.

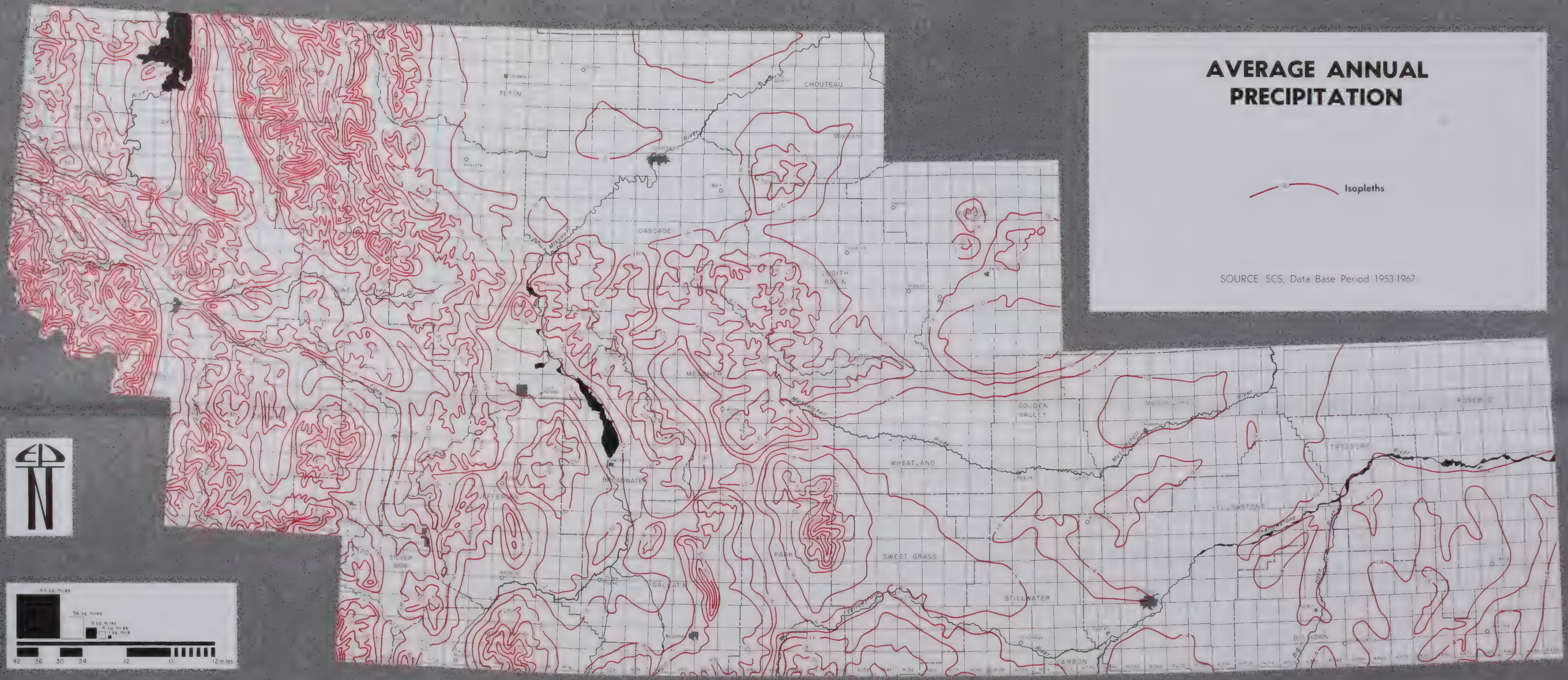
The average annual precipitation in the study area is shown on the Average Annual Precipitation Map for the 1953-1967 base period. This map illustrates the influence of topography in determining variation of total precipitation. Throughout the study area the greatest amounts of precipitation usually fall during the months of May and June. However, this maximum is more pronounced in the eastern plains, where over one-third of the annual total normally falls during these two months.

Variations in the average length of the freeze free season in the study area are shown on the accompanying map, taken from Caprio (1965). Again the influence of topography is evident. The average freeze-free season varies from fewer than 30 days in the high mountains to more than 135 days in the river valleys in the eastern plains. The relatively long growing season, warm summers, and precipitation maximum occurring in late spring-early summer are climatic conditions which make agriculture viable in the arable regions of the eastern plains (U.S. Dept. of Commerce 1971). Table 1 in Appendix A4 Volume 3b lists the probability of the occurrence of a freeze-free season shorter or longer than the average values given on the map.

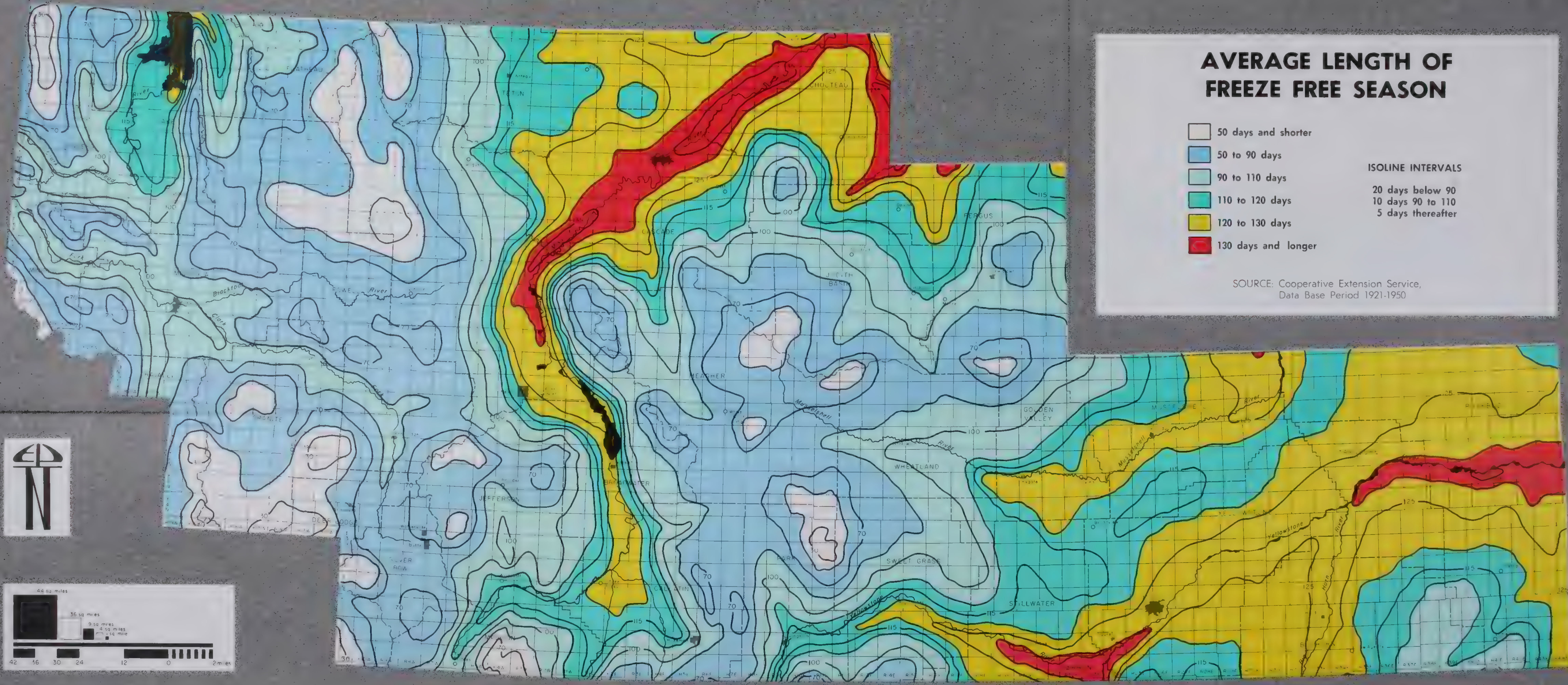
The climatic features most relevant to transmission line corridor selection are those parameters relating to line reliability, such as lightning incidence, tornado and other severe wind frequencies, icing zones, and those weather effects relating to corona discharge, including air density, humidity, and foul weather frequencies. Data with sufficient areal coverage and resolution to provide a basis for corridor selection are not available.

Climatic data will therefore not be considered explicitly in corridor selection. Climatic influences will be included implicitly in the evaluation of the corridor impacts on vegetation, erosion potential, and wildlife habitat.

AVERAGE ANNUAL PRECIPITATION



SOURCE SCS, Data Base Period 1953-1967



AVERAGE LENGTH OF FREEZE FREE SEASON

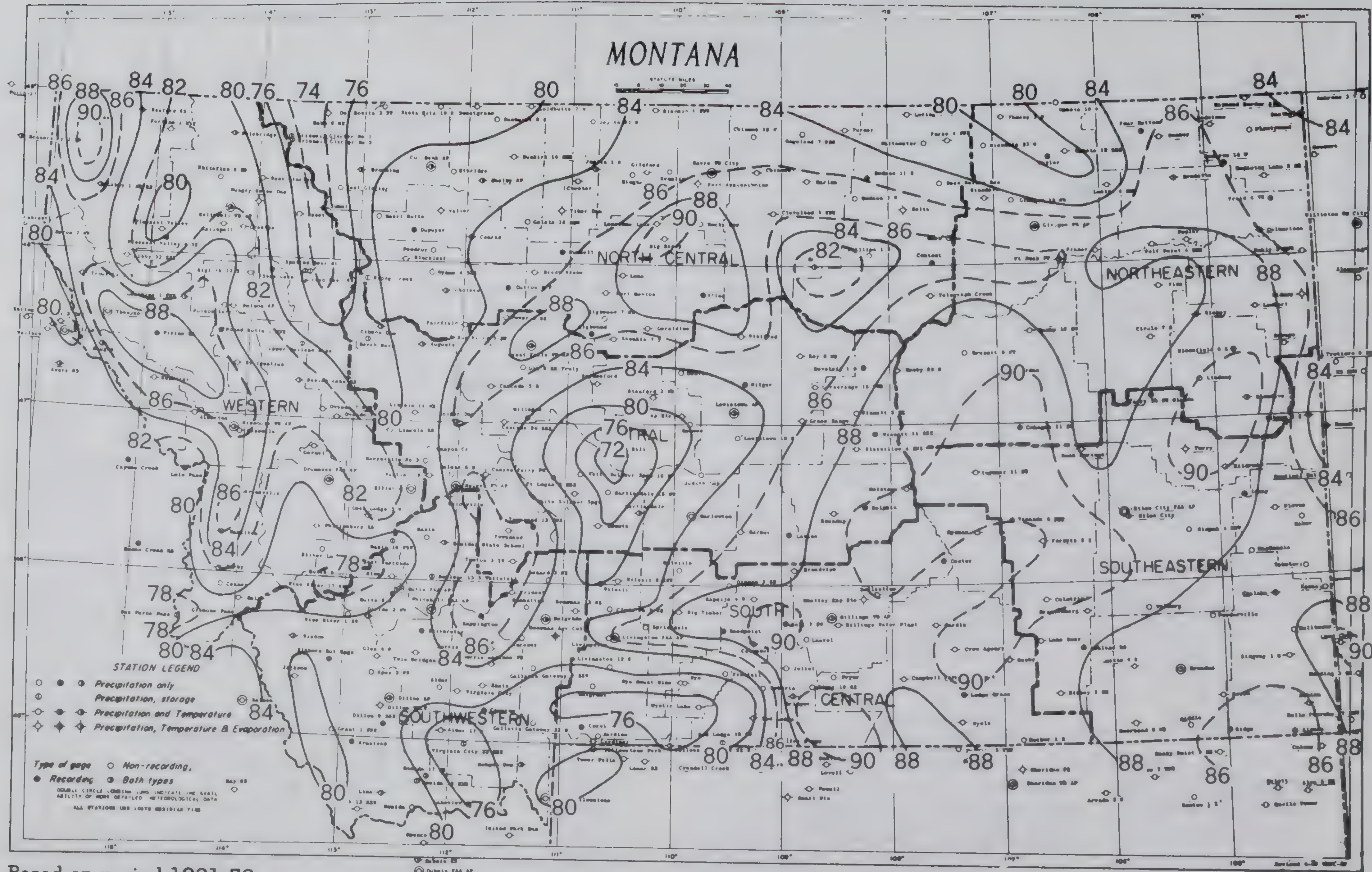
- ⬜ 50 days and shorter
- 🟦 50 to 90 days
- ▨ 90 to 110 days
- 🟩 110 to 120 days
- 🟨 120 to 130 days
- 🟥 130 days and longer

ISOLINE INTERVALS

20 days below 90
10 days 90 to 110
5 days thereafter

SOURCE: Cooperative Extension Service,
Data Base Period 1921-1950

Mean Maximum Temperature (°F.), July



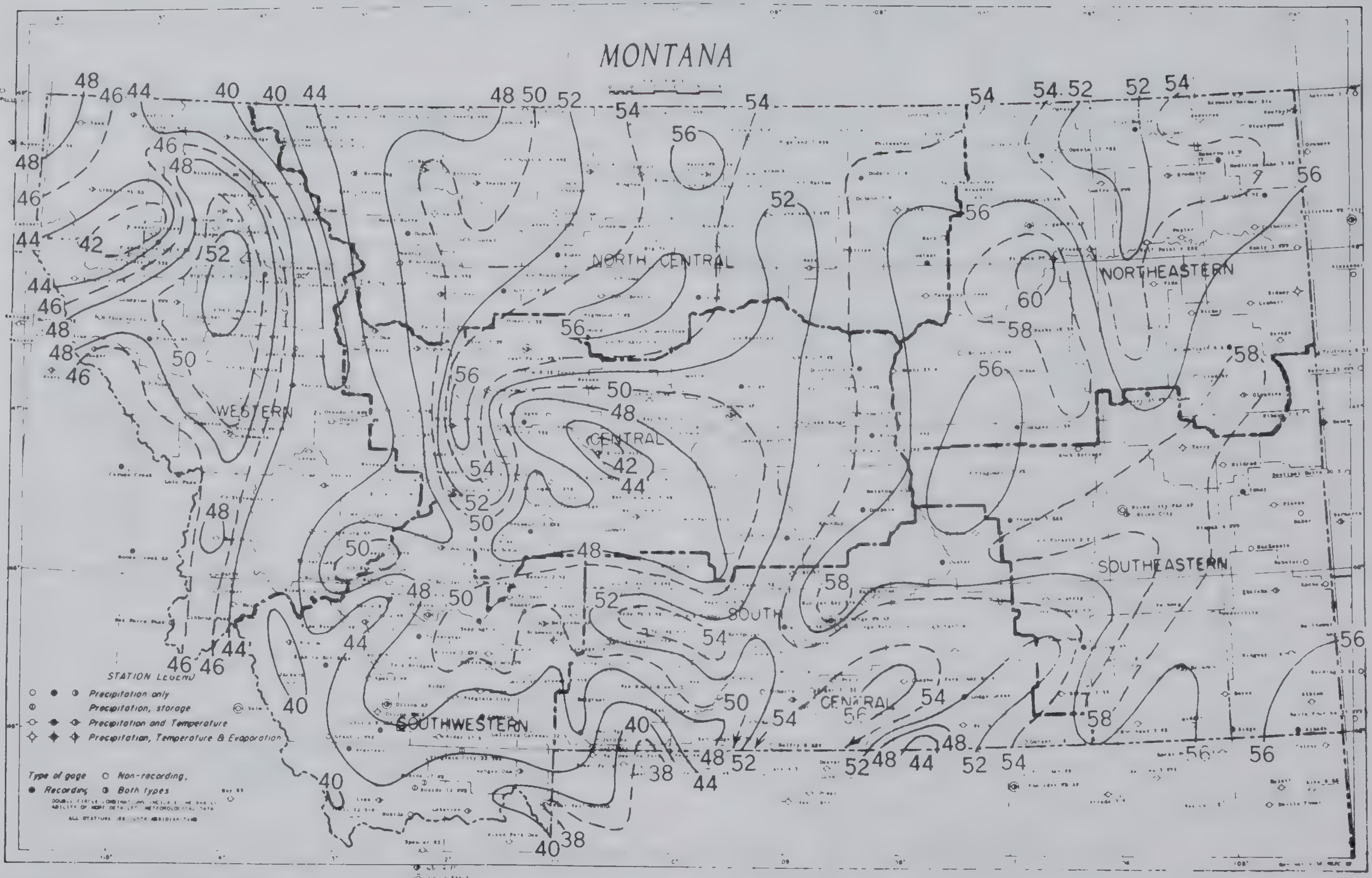
Based on period 1931-52

USCOMM-WB-ASHEVILLE

Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas.

Figure 5-22

Mean Minimum Temperature (°F.), July



Based on period 1931-52

USCOMM WB ASHEVILLE

Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas.

Figure 5-23

5.2. Cultural Environment

5.2.1. Existing Land Use

5.2.1.1. Land Use Categorization

A. Linear Patterns

The present pattern of corridors within the study area, shown on the following two maps, Land Use-Linear Patterns--Transportation and Land Use-Linear Patterns--Utilities, is a function both of the topography of the land and of the historic development of transportation and population centers in Montana. Comparison of these maps reveals that, in many cases, the same corridors are used simultaneously for a variety of linear structures, e.g., highways, railroads, pipelines, and power lines. This is a consequence of the fact that linear patterns are subject to similar site restrictions, and together tend to follow areas of least environmental "friction". The factors leading to the existing pattern of major corridors should be understood before any plan is implemented to impose a new corridor upon the landscape.

The presence of these corridors places certain restrictions upon other types of land use, and it is important to consider whether the impact of a new linear structure would be greater following an existing corridor or traversing a new area not presently crossed by a linear structure. Unfortunately, the areas most convenient for corridor location are often those most highly suited for other land uses, e.g., agricultural and residential, with which linear patterns may be incompatible.

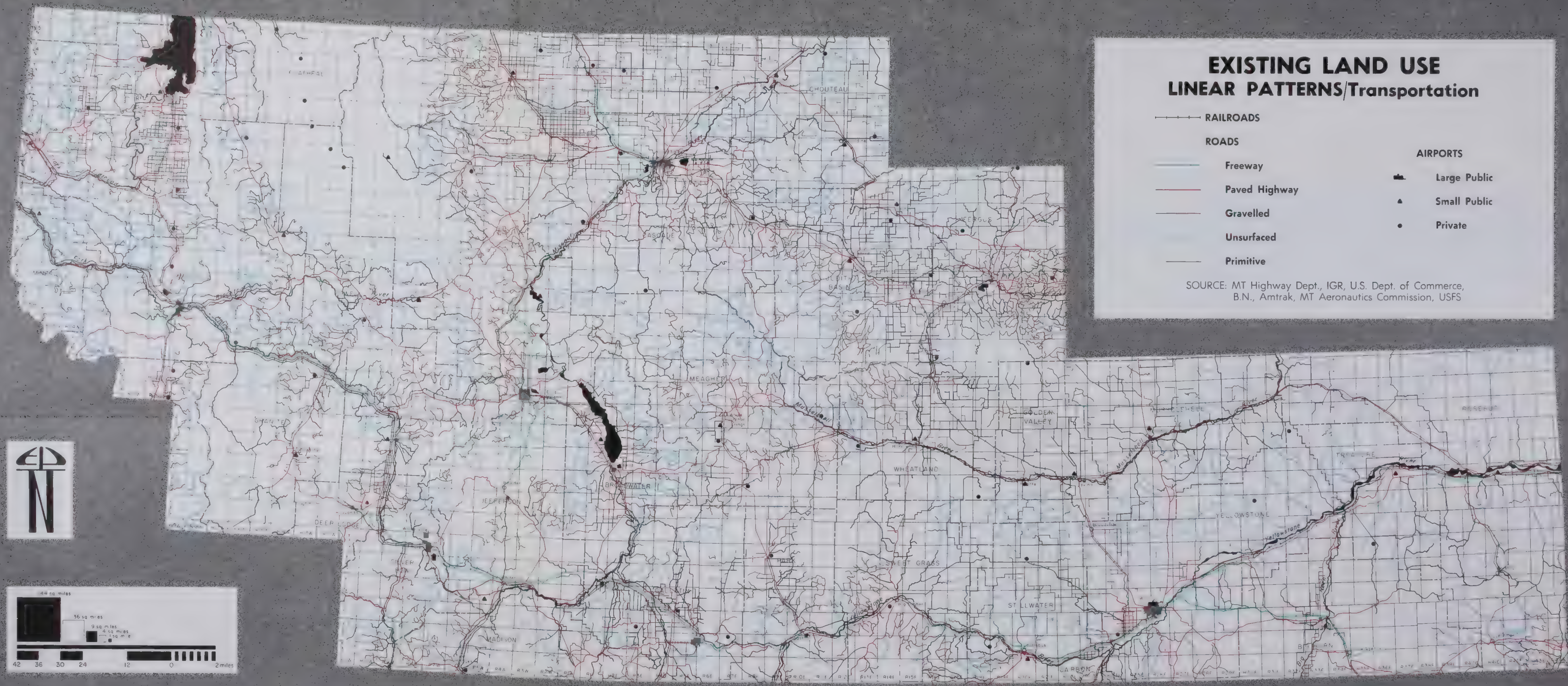
1. Transportation

The present pattern of major transportation corridors in the study area emerged relatively early in the history of Montana. In the days of homesteading and settlement, immigration into the region was primarily in a westerly direction from eastern population centers, notably Minneapolis-St. Paul, Chicago, and St. Louis. During this period, topographic features were of prime importance in channeling movements of men across the continent.

The early east-west transportation routes tended to follow river valleys, notably those of the Lower Missouri and Yellowstone, where the topography is relatively flat. In the mountainous western regions of the study area, early roads were restricted to valleys and to the lower mountain passes. Population centers developed along these early major corridors, especially in the eastern portion of the study area where nearly all major cities and towns are located along the Yellowstone River. The present pattern of transportation corridors strongly reflects this historic development.

a. Roads

Portions of Interstate Highway 90 follow the most important east-west corridor in the study area. The corridor parallels the Yellowstone River west to Livingston, then continues northwestward through Bozeman, Butte, and Deer Lodge to Missoula. Two major north-south highways cross the study area; these are Interstate 15, which connects Dillon, Butte, Helena, and Great Falls, and U.S. 93, which follows the Bitterroot Valley



EXISTING LAND USE
LINEAR PATTERNS/Transportation

RAILROADS

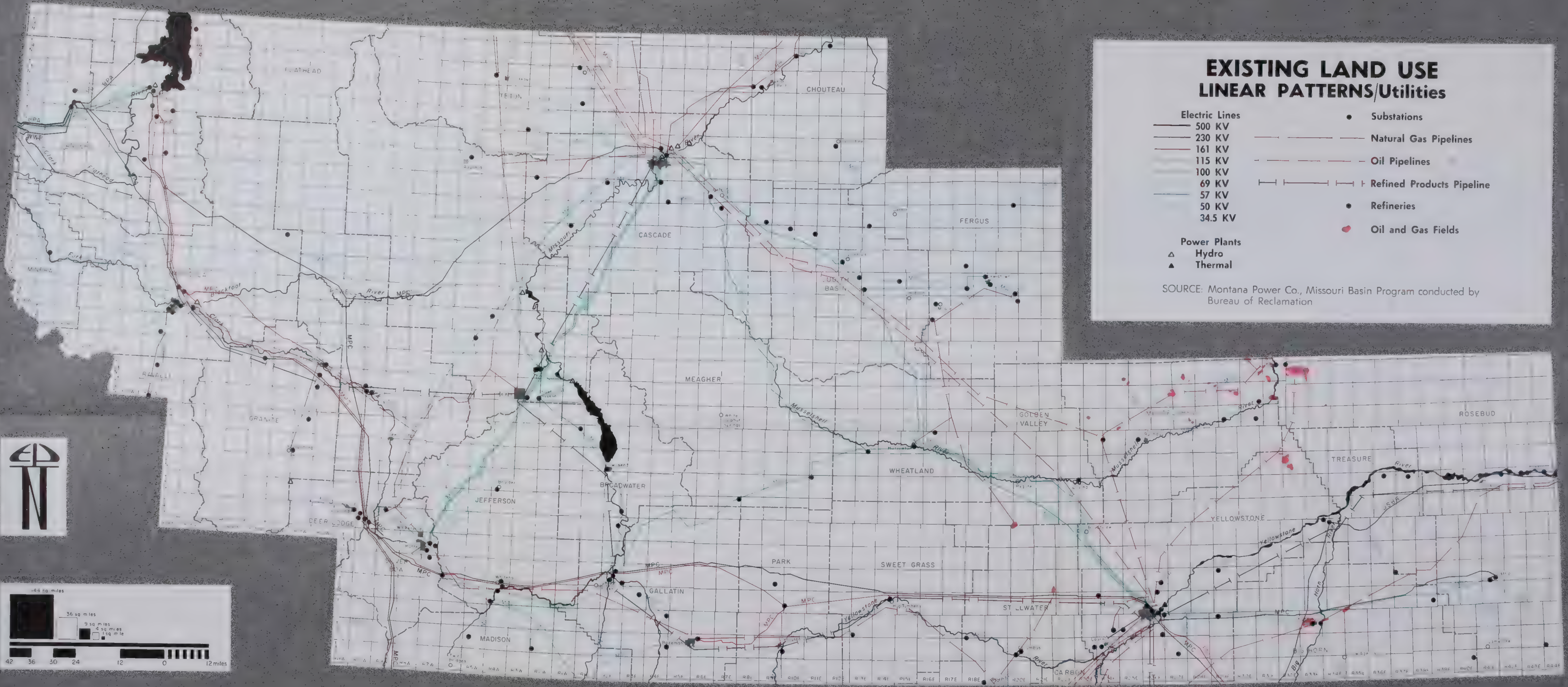
ROADS

Freeway	
Paved Highway	
Gravelled	
Unsurfaced	
Primitive	

AIRPORTS

- Large Public
- ▲ Small Public
- ● Private

SOURCE: MT Highway Dept., IGR, U.S. Dept. of Commerce, B.N., Amtrak, MT Aeronautics Commission, USFS



EXISTING LAND USE
LINEAR PATTERNS/Utilities

Electric Lines	
500 KV	Substations ●
230 KV	Natural Gas Pipelines
161 KV	
115 KV	Oil Pipelines
100 KV	
69 KV	Refined Products Pipeline
57 KV	
50 KV	Refineries ●
34.5 KV	Oil and Gas Fields

Power Plants
△ Hydro
▲ Thermal

SOURCE: Montana Power Co., Missouri Basin Program conducted by Bureau of Reclamation

northward from Lost Train Pass through Hamilton and Missoula, and continues north to Kalispell. These routes and other federal, state, and county roads are shown on the Linear Patterns-Transportation Map. Unsurfaced and primitive roads are also shown; these are important in providing construction and maintenance access to the proposed transmission line, but are not maintained and are impassable much of the year.

b. Railroads

Railways are subject to the same topographic restrictions that pose limitations on highway alignments, and thus railroad corridors parallel highways throughout much of the study area. However, there are many instances in which the two diverge and follow separate routes. Freight lines in particular are not as intimately connected with minor population centers as are highways. The major freight railway in the study area is the Burlington-Northern main line, which is followed closely by the I-90, I-94 east-west corridor (see Land Use-Linear Patterns-Transportation Map). This line has branches from Billings to Great Falls, Logan to Helena to Garrison, and Butte to Helena to Great Falls. A Chicago-Milwaukee line and a Union Pacific line also cross the study area; the latter also is followed by the I-90 corridor from Logan to Missoula. East-west passenger service is offered by the Amtrak line, which follows the Burlington-Northern corridor and therefore the I-90, I-94 corridor.

c. Airlines

The major airlines serving the study area are Northwest Orient, Frontier, and Western Airlines. The locations of airports, heliports, and landing strips in the study area are shown on the transportation map.

2. Utilities

a. Electric Transmission Lines

In the eastern portion of the study area, transmission lines tend to follow major corridors such as along the Yellowstone River, but the siting of transmission structures is subject to fewer topographic restrictions than that of roads. Unlike transportation corridors, major high-voltage transmission lines need to connect only major load centers, and often cross upland benches in a straight line between generating plants and load centers, ignoring minor undulations in topography and agricultural land use patterns. In the mountainous western portion of Montana, transmission line corridors usually follow the major highways (especially I-90 and I-15) because the problems of maintenance are more severe, but in some instances the lines cross forested mountain areas to minimize distance. The only existing 500 KV line in the study area runs southwestward from Hot Springs to Idaho. Data on existing power generating plants, substations and electric transmission lines found in the study area are discussed in Section 3.3.1.

b. Gas Pipelines

Natural gas fields are located in Big Horn County near Hardin, in Stillwater County, and in Golden Valley County. Pipelines carrying natural gas to population centers tend to follow the major transportation corridors discussed above.

c. Oil Pipelines

Nearly all the oil fields in the study area are found in Musselshell, Rosebud, and Yellowstone Counties. As shown on the Linear Patterns-Utilities Map, these fields are connected by pipelines to the Cenex refinery in Laurel, the Humble and Continental refineries in Billings, and the Phillips refinery in Great Falls. Pipelines carrying refined products radiate from the refineries at Billings and Laurel.

B. Site Patterns

Land use site patterns are limited by physical features of the environment, such as topography, water availability, physiography, vegetative cover, climate, and soil capability, and by cultural factors, such as the location of population centers, transportation routes, and power sources. Within the study area, land use can be categorized into the following classes:

1) Agricultural land use, which includes irrigated land, dry cropland, and rangeland;

2) Urban and residential land use, which includes urban areas, small communities and scattered built-up areas;

3) Industrial land use;

4) Woodlands;

5) Water areas;

6) Recreational land use includes state parks, campgrounds, other terrestrial-related activities-natural oriented, other terrestrial-related activities -- cultural-oriented, other water related activities, points of interest, national register historic sites, other historic sites, and archaeologic sites.

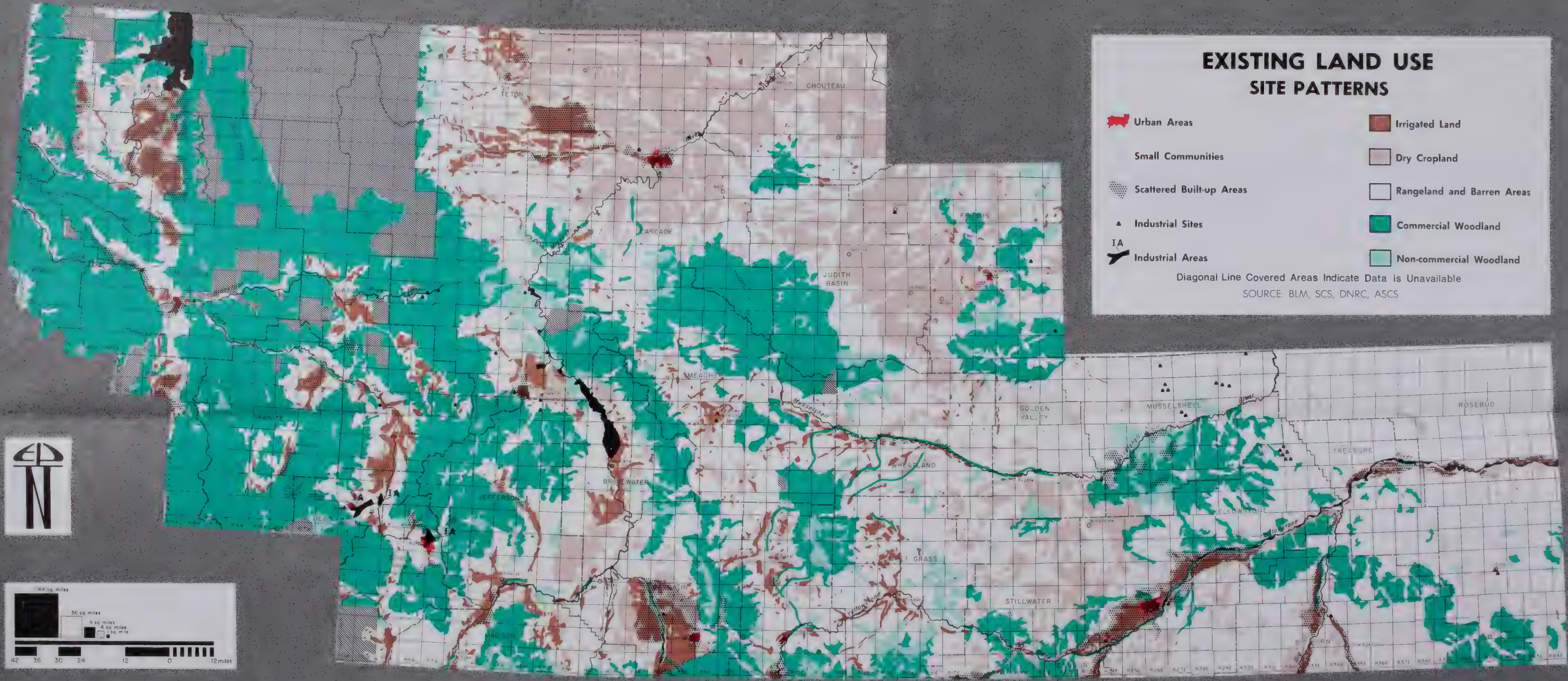
7) Specially managed areas.

The amount of non-federal land within several of these major land use categories for the counties in the study area is summarized in Table 1 of Appendix M, "Land Use--1958 and 1967". This table and the following definitions were adapted from "The Montana Soil and Water Conservation Needs Inventory" (SCS 1970). Site patterns of land use within the study area are shown on the map of that title.

1. Agricultural Land Use

a. Irrigated Land

Irrigated land is that acreage to which water is applied on a recurring basis. As seen on the Site Patterns Map, irrigated lands are found most exclusively along major river valleys and in floodplains where water is readily available. The amount of irrigated land in the study area is increasing as various state and federal irrigation programs are being implemented. There has been a recent shift from flood and ditch irrigation to sprinkler irrigation throughout the study area. Sprinkler irrigation systems help eliminate pollution from return flows, reduce the quantity of the water diverted from streams and improve irrigation efficiency and crop production, but



EXISTING LAND USE

SITE PATTERNS

they require large unobstructed tracts of land for efficient operation.

Irrigated land produces hay, grains, row crops, and pasture; an increasing amount of irrigated land is being used for hay production. Average yields per acre for both irrigated and non-irrigated cropland are summarized in Table 3 of Appendix M, which was prepared from data furnished by the Montana Crop and Livestock Reporting Service (1972). Acreages of irrigated and non-irrigated cropland for each of the counties within the study area are given in Table 2 of Appendix M.

b. Dry Cropland

Dry cropland is that acreage on which crops receive no supplemental water on a recurring basis. Wheat is the most important grain produced in the study area, followed by barley, oats, and corn. Dry cropland is the dominant land use in the semi-arid steppe region in Teton, Cascade, Chouteau, Judith Basin, Wheatland, and Golden Valley Counties.

The dry cropland areas shown on the Site Patterns Map include summer fallow, or lands left idle during alternate years to store the needed moisture to make crop yields profitable in the semi-arid climate. Strip farming, or the practice of leaving alternate strips of land as summer fallow during alternate years, is predominant throughout most of the study area. Types of crops and average yields for counties within the study area are shown in Table 3 of Appendix M. Production of grains within the study area is decreasing as more cropland is converted to forage production (hay and pasture).

c. Rangeland

Rangeland is defined as land producing forage plants, either introduced species (pasture) or native species (native range), which are not cut for hay but are generally grazed. The species composition of native range in the study area is discussed in Section 5.1.4. Cattle are the most important grazers on rangeland throughout the study area; sheep and horses are less abundant. The rangeland land-use category shown on the Site Patterns Map includes, in addition to grazable grassland, barren areas which do not produce forage plants and which are in practice never grazed by livestock. These "barren" areas include badlands, talus slopes, cliffs, alpine summits or rocky mountainous summits. The importance of these areas as habitat for game and non-game wildlife species is often overlooked. The importance of the rangeland resource to game birds and mammals can be seen by a comparison of the Site Patterns and Wildlife Maps. Range capabilities in animal unit months are discussed in Section 5.1.4. Livestock production in the study area is summarized in Table 4 of Appendix M.

2. Urban and Residential Land Use

a. Urban Areas and Small Communities

Urban areas include cities and towns greater than 2500 in population; small communities are towns with a population from 100-2500. These are centers of high population density, typically containing residences or commercial establishments crossed by a network of roads dividing groups of residences into blocks. The pattern of urban land use precludes other types of land uses on the same area, since most of the land surface is covered by structures or roads. Institutional and public administrative sites are usually located within urban areas, and industrial sites may also be located within areas of high population density. Urban areas comprise less than 1% of the land in the study area, and most urban land is concentrated in a few major cities (see Section 5.2.4.1.).

b. Scattered Built-Up Areas

This land-use category includes towns of less than 100 persons, scattered residences with a density of at least five dwelling units per square mile (such as rural subdivisions and trailer parks), large airports, and scattered commercial or institutional sites. In these areas, individual housing or commercial units are located in close proximity to each other, but do not attain the density of urban areas.

Scattered rural residences are increasing in the study area, especially in the rural areas surrounding Hamilton, Missoula, Bozeman, Helena, Laurel and Billings. Table 5 of Appendix M shows that a considerable number of acres in each county in the study area have been subdivided. Agricultural land taken out of production by this kind of development is lost permanently.

3. Industrial Land Use

Industrial areas shown on the Site Patterns Map include non-urban factories, tailing ponds, slag piles, ash ponds, and other areas where the site or effluents from industrial operations preclude the possibility of other land uses. Industrial operations or wastes cover relatively large areas near Anaconda, Butte, and Billings. With the exception of the Berkeley Pit at Butte mines are not indicated on the Site Patterns Map. Mineral deposits occurring in the study area are shown on the U.S.G.S. maps (1967) locating mineral occurrences in Montana as inventoried by C. B. Bently and George Mowat; operating mines are listed in the Directory of Mining Enterprises (1974) compiled by the Montana Bureau of Mines and Geology. There are no major strippable coal deposits between Colstrip and Hot Springs.

4. Woodlands

Woodlands in the study area may be classified as commercial forest (capable of producing crops of industrial wood) and noncommercial forest (incapable of yielding crops of industrial wood). Noncommercial forests include forest land stocked by species that have no value commercially or land which is withdrawn from timber utilization.

Commercial forests are a major land use category in much of the mountainous western portion of the study area, and the harvest of commercial timber is quite important to the economy of this region. Average annual timber harvest, species composition, timber size, and stocking of forests in the study area are discussed in Section 5.1.4. . Grasses and forbs occurring in the understory of woodlands are an important source of forage for cattle, especially in this western region, and are discussed in Section 5.1.4. In addition, woodlands provide habitat for a large number of wildlife species.

5. Water Areas

The major lakes and reservoirs in the study area are shown on the Site Patterns and Surface Water Maps. Acreages of small water areas, i.e., ponds, reservoirs, and lakes from 2 to 40 acres in size and perennial streams less than 1/8 mile wide, are given in Table 1 of Appendix M.

6. Recreational Land Use

Montana has areas of high plains and areas of mountainous topography, both intersected by numerous streams and rivers; the majority of inhabitants live in pockets of dense settlement. Because of its physiographic and climatic variety, the state supports a wide diversity of plant and animal species. The combination of the factors creates in Montana a unique natural resource for national recreation.

Because of Montana's great diversity in available recreation types, broad categories have been utilized to incorporate similar forms of recreation. There are two basic aspects to recreation: the activity itself and the location at which the activity takes place. Elements implying recreational activity, such as boat ramps, are incorporated in the inventory. The basis for the categories is the relationship between an activity (such as fishing), a facility (such as a fishing access road), and the environment (in this case the presence of water is required).

The specific inclusions of each category are given at the end of this section, but these categories do not represent all forms and places of recreation. The more popular forms of recreation are included. The Recreation and Cultural Features Map primarily locates activity areas that have concentrated use, such as golf courses, and also sites of public interest, such as fossil locations or historic sites. Ownership, whether public or private, was included in the inventory, but was not indicated on the map or in the categorical classification, because the recreational activity was available to the public no matter what agency or individual administered the activity.

The nature of certain forms of recreation, such as cross-country skiing, preludes exact location, and therefore the areas indicated on the Specially Managed Areas Map would partially represent the areas in which these activities occur.

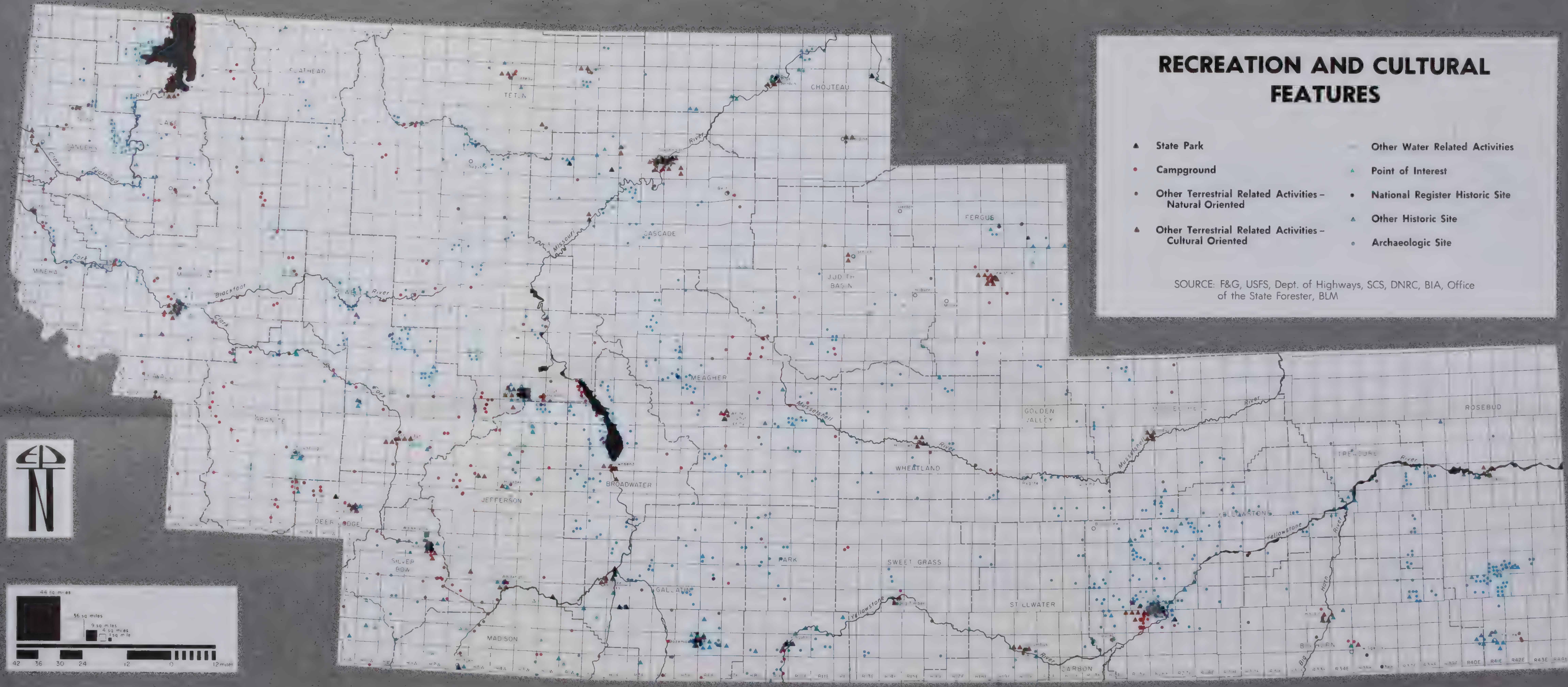
The following categories delineate the majority of sites critical for recreation in the study area:

a. State Parks

There are seven state parks in Montana; four are in the study area. These sites were established to preserve certain natural features and provide recreational facilities. State monuments are also mapped in this category because they provide the same functions as state parks except overnight camping.

b. Campgrounds

Included are designated campgrounds



RECREATION AND CULTURAL FEATURES

- ▲ State Park
- ● Campground
- ● Other Terrestrial Related Activities – Natural Oriented
- ▲ Other Terrestrial Related Activities – Cultural Oriented
- — Other Water Related Activities
- ▲ Point of Interest
- ● National Register Historic Site
- ▲ Other Historic Site
- ● Archaeologic Site

SOURCE: F&G, USFS, Dept. of Highways, SCS, DNRC, BIA, Office of the State Forester, BLM

administered by public or private agencies; many of which are multi-purpose recreation areas also offering fishing and hiking. Most of the privately managed areas are separate entities, while the publicly managed areas are usually associated with large acreages of publicly owned land, such as national forest. In 1972, camping occupied 3.6% of all adult Montanans' recreation time, and 4.7% of all children's activity time; it is also partially responsible for attracting out-of-state tourists who spent 210 million dollars in Montana in 1973.

c. Other Terrestrial-Related Activities - Natural-Oriented

This category includes specific natural oriented, terrestrial recreation activities and locations not within areas covered in categories a or b. The natural environment is the prime factor in the quality of this form of recreation and is an integral part of the success and pleasure of the recreational activity. Elements of this category include picnic grounds, rest areas, scenic vistas, ski areas, horseback riding facilities and designated snowmobile trails.

d. Other Terrestrial-Related Activities - Cultural-Oriented

Forms of cultural-oriented, terrestrial recreation, other than those located in a and b, are grouped here. The site itself is the prime factor in the following recreational activities, which are primarily urban-oriented. This category includes baseball fields, tennis courts, golf courses, museums, and fairgrounds.

e. Other Water-Related Activities

Activities that primarily depend on the presence of water and that are not located within categories a and b are grouped here. This category includes fishing access sites, boat ramps, swimming areas, marinas, and recreational areas, and swimming, boating, and fishing.

f. Point-of-Interest Sites

Ghost towns are one of the more popular destinations for those Montanans who drive for pleasure, an activity which accounts for 18.4% of all recreation time. Geologic interest sites, fossil locations, gem fields, mineral locations and near-pristine areas account for most other activity in this category.

g. National Register Historic Sites

There are 26 historic sites in the study area that are listed in the National Register of Historic Sites. These sites include buildings, memorials, battlefields, and other places important in the historic development of the United States.

h. Other Historic Sites

Sites other than those described in category g that are also significant in regional, state, and local history have been mapped; those of established merit are listed in the Montana Historic Sites Compendium (1974), and the others await further study.

i. Archaeologic Sites

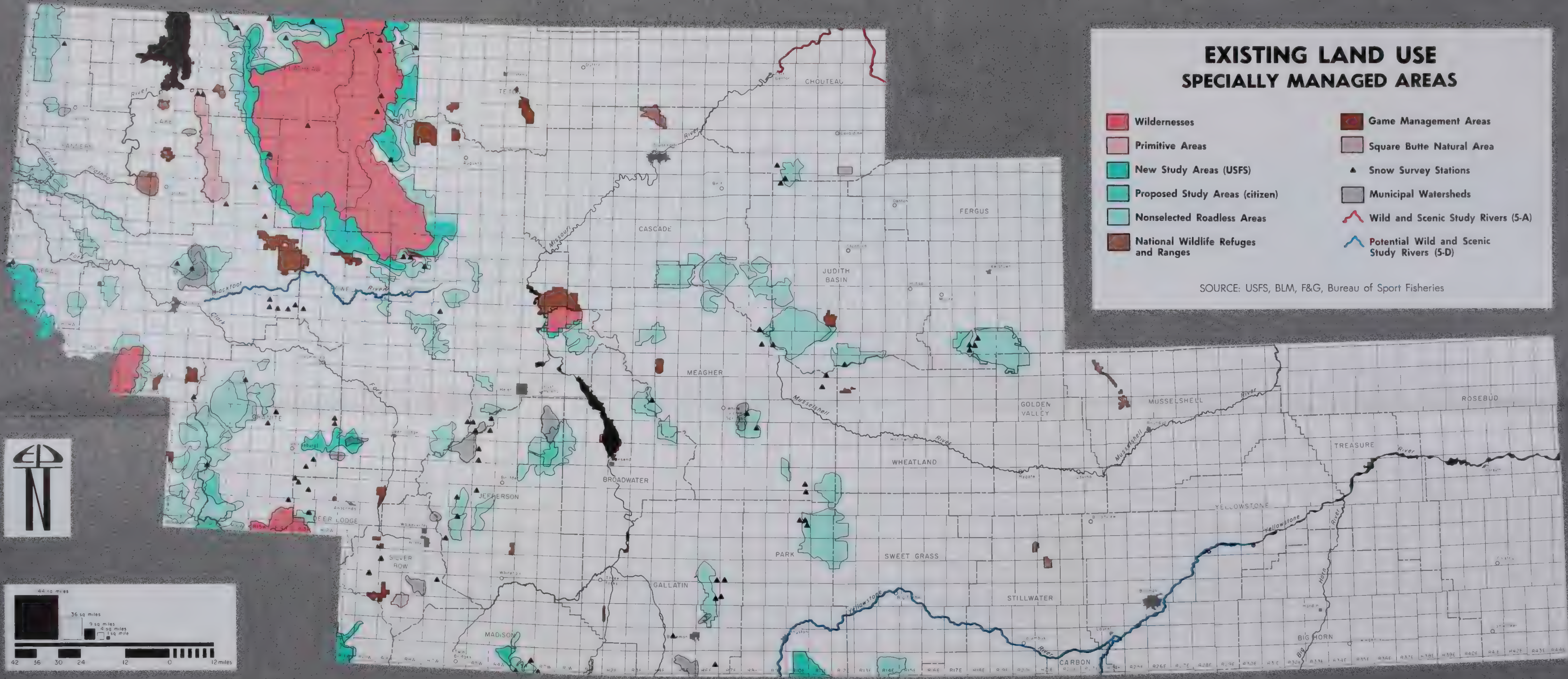
These sites have been identified from the files of pertinent departments at the University of Montana and Montana State University. Almost 2000 sites were documented in the inventory, representing sites that have been investigated and those that are known and are awaiting further study. These sites have been identified only by the section in which they occur, to prevent unauthorized scavenging.

7. Specially Managed Areas

Wilderness, primitive areas, new study areas, nonselected roadless areas, citizen proposed study areas, national wildlife refuges and ranges, game management areas, and other areas containing land use constraints which might limit their short term consideration as possible routes for transmission line corridors are shown on the Specially Managed Areas Map. These categories represent areas of: (1) legally classified land use associated with the protection of their natural condition, or (2) specific management based on detailed land use plans, or (3) special management pending completion of detailed land use plans. In addition, some snow survey stations and municipal watersheds are shown on the map.

The study area includes all or part of five wilderness areas, the Bob Marshall, Scapegoat, Anaconda-Pintlar, Gates-of-the-Mountains, and Selway-Bitterroot, which are listed in Table 8 of Appendix M, "Wildernesses".These areas are managed by the U.S. Forest Service under the National Wilderness Preservation Act of 1964 to preserve and protect their natural condition. Under the National Wilderness Preservation Act, logging, road building, motorized travel, and the construction of permanent installations such as transmission lines are prohibited. In order for a transmission line right-of-way to be routed through an area presently classified as wilderness, that portion of the area would need to be declassified by an act of Congress or be authorized by the President of the United States as necessary in the public interest. Normally, this would only be done in case of national emergency. The criteria for declassification and the period of time involved are such that, for the purposes of the present study, wilderness areas can be excluded from short-term consideration as possible routes for the proposed Colstrip-Hot Springs 500 KV transmission lines.

Three primitive areas, listed in Table 9 of Appendix M, are located in the study area. The Beartrap Canyon and Humbug Spires Primitive Areas are managed by the U.S. Bureau of Land Management. The Mission Mountains Primitive Area is managed by the U.S. Forest Service and is presently being considered by Congress for wilderness classification. Until acted upon by Congress, this area is protected by the same restraints as an existing wilderness area and requires the same action for granting of a transmission line right-of-way. New study areas, listed in Table 10 of Appendix M, are areas of National Forest land which have been selected by the USDA Forest Service for further study to determine if they should be recommended to Congress for addition to the National Wilderness Preservation System. They are managed to protect their wilderness characteristics until detailed studies can be completed and a land use recommendation reached. Before any



EXISTING LAND USE
SPECIALLY MANAGED AREAS

permanent installations such as transmission lines can be allowed to cross a new study area, a detailed land-use study must be prepared and presented as a public environmental impact statement, and the alternative of wilderness classification must be considered. The time frame involved in preparing these studies is such that these areas may be ruled out for short-term consideration as possible routes for the proposed facilities. Study areas proposed under the Montana Wilderness Study Act of 1974 are discussed in Section 5.2.2. (Proposed/Potential Land Use).

Certain roadless areas not designated as new study areas by the U.S. Forest Service have been classified as nonselected roadless areas; those within the study area are listed in Table 11 of Appendix M, "Nonselected Roadless Areas". These areas possess wilderness qualities which are protected from developments and may be designated as new study areas by action of the Chief of the U.S. Forest Service or Congress. In order for these areas to be open to such development as the routing of a transmission line corridor, a land-use study similar to that required for new study areas must be prepared, thus eliminating these areas from short-term consideration for the routing of the proposed facilities.

The study area contains eight national wildlife refuges as well as the National Bison Range, which are listed in Table 12 of Appendix M, "National Wildlife Refuges". Managed by the U.S. Bureau of Sport Fisheries and Wildlife, these areas consist of unusually productive or critical wildlife habitat (primarily waterfowl breeding and wintering areas) which are protected from land use activities which may be detrimental to their wildlife populations. The National Bison Range, located within the Flathead Indian Reservation, supports a herd of approximately 325 bison as well as herds of elk, bighorn sheep, mountain goats, mule deer, white-tailed deer, and antelope. It is managed to maintain herds of native animals in a natural and undeveloped environment for the enjoyment of the public (Kaschke 1974).

Game management areas found within the study area are listed in Table 13 of Appendix M, "Game Management Areas". These lands are controlled by the Montana Fish and Game Commission and managed for the protection of certain areas of critical game habitat (primarily elk winter range). A considerable amount of land is owned by the Montana Fish and Game Department, but also included is land leased from federal agencies or private landowners. The policy of the Fish and Game Commission is to protect these areas from developments which would have adverse effects upon wildlife. In order for a transmission line right-of-way to cross Fish and Game ownership within a game management area, the Fish and Game Commission would have to grant permission for an easement. Lands deeded from the Nature Conservancy, a private conservation group, would have to be condemned, and other lands would require easements from the individual landowners of administrative agencies (Brown 1974).

The Wild and Scenic Rivers Act of 1968 provides for certain selected rivers in the United States to be preserved in free flowing condition and, with their immediate environments, to be protected from developments which would preclude or limit classification until a final decision is reached. Although there are no designated wild and scenic rivers in the study area, the Missouri River from Fort Benton to Ryan's Island is designated as a "5-A" Study River, i.e., one which is to be studied and possibly recommended for inclusion in the Wild and Scenic River System. This section of the river is protected from transmission line right-of-way easements until the study, which has recently been completed, has been acted upon. In addition, sections of three other rivers, the Yellowstone, Madison, and Blackfoot, have been selected by the Secretary of the Interior as "5-D" Potential Study Rivers. Such rivers would require study should a federal water project be proposed, but are not presently under legal protection against the routing of transmission lines. However, the routing of a transmission line near or across one of these rivers may alter the potential of future designation as a wild and scenic river (Loucke 1974).

In addition to the above categories, the Square Butte Natural Area, managed by the U.S. Bureau of Land Management, is shown on the Specially Managed Areas Map. Also shown on the map are some snow survey stations and municipal watersheds, which are discussed in Section 6.1.2. Snow survey stations are sites where snow water content is measured periodically for use in forecasting stream flow during the remainder of the year. Nearby timber removal operations such as those required for transmission line right-of-way clearing may alter the pattern of snow deposition and affect the historical basis for forecasting stream flow. Municipal watersheds are mountain precipitation catchment areas whose runoff supplies cities with domestic water; transmission line construction operations near these areas may affect the hydrologic characteristics and water quality of the watershed (see Section 6.1.2.).

5.2.2. Proposed/Potential Land Use

5.2.2.1. Land Use Categorization

A. Linear Patterns

1. Transportation

The Montana Highway Department (1974) plans no major new corridors through the study area from 1974 to 1979. Construction outlined in its five-year plan is primarily maintenance or improvement of existing transportation corridors. In certain cases, such as the Melstone-Mosby secondary, the new road would be constructed up to several miles from the existing road, but would still follow the same general corridor. Construction is continuing along the interstate systems.

New railroad spur lines may be constructed, but there are no plans for major new railways in the next several years.

It is unlikely that any new major airports will be constructed in the study area, although more private landing strips are being built on large ranches in the eastern part of the study area.

2. Utilities

Montana Power Company (1974) lists 10 proposed electric transmission lines to be built before 1979, excluding the Colstrip-Broadview 230 KV line and the Colstrip-Hot Springs twin 500 KV lines, which are listed in Table 6 of Appendix M, "Montana Power Scheduled Electric Transmission Lines". A 500 KV line from Hot Springs, Montana, to Bell, Washington is scheduled by BPA. Additional lines may be proposed by Montana Dakota Utilities, BPA, the U.S. Bureau of Reclamation, Pacific Power and Light, or local Rural Electrification Associations to serve local need.

The development of future coal-fired generating plants may entail construction of additional transmission lines. Similarly, pipelines would need to be constructed to transport products of possible future coal gasification or liquification plants which may be constructed in connection with coal development in eastern Montana.

B. Site Patterns

1. Agricultural Land Use

a. Irrigated Land

The location of potentially irrigable land in the study area is shown on the Potential Land Use Map, which was prepared from data furnished by the Water Resources Division of the Department. The lands classed as irrigable are defined as those lands having "soil, topography and climate that will support sustained irrigated agriculture with proper water management, drainage, and other necessary conservation practices", and which are suitable for irrigation by gravity or sprinkler methods (Montana DNR&C 1974a). These potentially irrigable lands are grouped into three classes:

Class 1, only slight limitations;

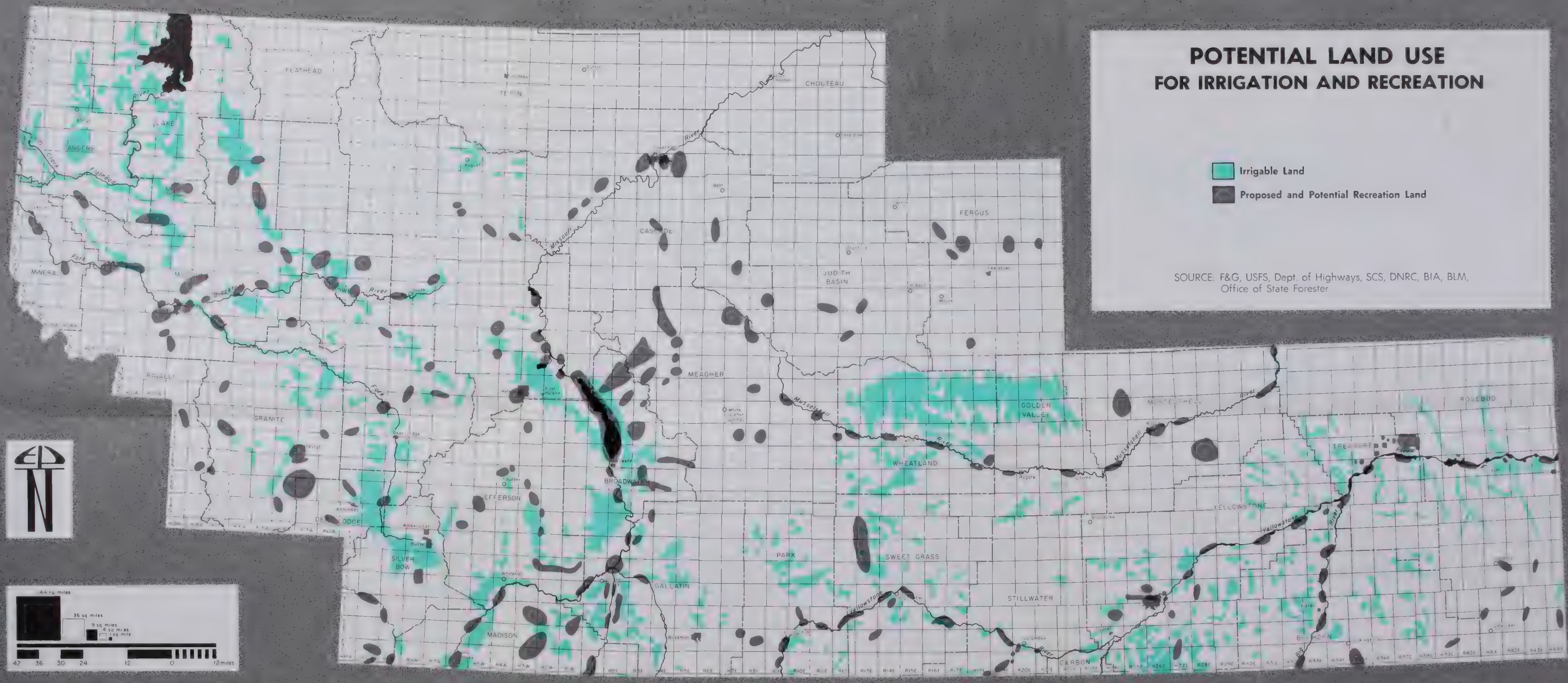
Class 2, moderate limitations; and

Class 3, severe limitation.

This classification of land as "irrigable" does not take into account the availability of water for irrigation or market factors of the crops produced. Much "irrigable" land will probably never actually be irrigated due to the lack of available water in arid or semi-arid regions, although it may be cultivated as dry cropland. The amount of irrigated land in the study area is increasing, as mentioned before, and much of the newly irrigated land is irrigated by sprinkler systems. These are normally operated by gasoline or electric pumps, and the trend toward powered sprinkler irrigation is indicated in Table 7 of Appendix M, which shows an accelerating increase in the rate of horsepower used by irrigation pumps.

b. Dry Cropland

Some dry cropland is potentially irrigable and may someday be irrigated. The county acreages of dry cropland and the value of the production from those acres for 1971 is inventoried in Table 2 of Appendix M.



POTENTIAL LAND USE FOR IRRIGATION AND RECREATION

SOURCE: F&G, USFS, Dept. of Highways, SCS, DNRC, BIA, BLM, Office of State Forester

c. Rangeland

The amount of rangeland in the study area will probably decrease in the future as more rangeland is cropped or committed to other land uses such as subdivisions or strip mining. This trend is evident for most counties in the study area.

2. Urban and Residential Land Use

a. Urban Areas

The locations of urban centers with population greater than 2,500 are well established in the study area, but the population limits to growth of currently expanding areas are not easily projectable. Massive energy development would be one factor that would affect future growth of all population centers in the study area, especially those in the eastern sector. The future pattern of urban land use will consist of the centrifugal expansion of suburbs around existing urban centers. Gustafson (1973) indicates that in the study area, as in the remainder of the state, there is a net movement of population from sparsely populated rural locations to urban or suburban areas.

Of the counties wholly or partially in the study area, Missoula, Jefferson, and Gallatin Counties have shown a population increase of 20% or greater from 1960 to 1970, while Golden Valley, Musselshell, Petroleum, and Treasure Counties have shown a decrease of 20% or more (Gustafson 1973). The cities of Missoula, Helena, Bozeman, Phillipsburg, Dillon, Hamilton, Billings and Hardin have shown a population growth rate of 27% or more in the ten-year period; this is greater than twice the U.S. growth rate. Anaconda, Butte, Livingston, Laurel, Roundup, and Forsyth have shown a decline in population in this same period. These trends in growth of certain urban areas at the expense of others will probably continue into the next decade.

b. Scattered Built-up Areas

The trends in urban growth discussed above extend into this land-use category also. People who must move near urban centers to find jobs, but who find urban or suburban life styles distasteful, tend to congregate in scattered built-up areas within commuting distance of cities. These rural residences generally take the form of subdivisions or trailer parks, and usually result in a sprawling, unplanned, or temporary residential area within a natural and agricultural setting. Despite zoning laws and subdivision regulations, the amount of land subdivided each year within the study area is increasing (Table 5 of Appendix M). This growth is of increasing concern in the communities, and to planning boards at the county and state level.

3. Industrial Land Use

The major area of industrial expansion will almost certainly be connected with the strip mining of coal and the associated mine-mouth generating plants and conversion plants in the extreme eastern portion of the study area, as discussed in Chapters 2, 6, and 9 of Volume 2 of this impact statement.

4. Woodland

Stands of commercial timber (shown on the Land Use Site Patterns Map) are, of course, potentially harvestable; the direction and extent of logging in the forested regions of the study area will depend both on demand and on the administrative policies of the U.S.F.S. and other major timber harvesters.

5. Recreational Land Use

Potential recreation lands have been identified by a survey of local, state and federal agencies. Some of these lands have already been incorporated into expansion plans for the near future, implementation of which has been delayed. The remainder of the sites represent lands which by their inherent qualities are suitable for long range consideration for recreational usage; the attributes responsible for inclusion of these properties vary, including historic, scenic, geographic, and others. Both private and publicly owned lands have been analyzed, but the validity of this inventory partially depends on land acquisition. The Land and Water Conservation Act makes revenue available to the state for recreational planning and implementation. Since its inception, approximately $20 million has been spent in acquisition and development of recreation sites in Montana. There is pending legislation in Congress to amend the Act to change the ratio of cost sharing from its current 50/50 to 70% federal-30% state on acquisition projects. The objective of the Act is to provide the greatest possible variety of outdoor recreation opportunities within the limits of available resources; outdoor recreation resources in balance range from intensively developed, mass-use areas to natural areas appealing to a smaller number of users.

Data was obtained from the following agencies: Department of Fish and Game, U.S. Forest Service, Department of Highways, Soil Conservation Service, DNRC, Bureau of Indian Affairs, Bureau of Land Management, and city and county governments.

6. Specially Managed Areas

As discussed in Section 5.2.1.1. (Existing Land Use-Site Patterns), primitive areas may be classified as wildernesses under the National Wilderness Preservation Act. Also, new study areas and nonselected roadless areas are areas possessing wilderness characteristics which have the potential of wilderness classification. In addition to these areas, certain other study areas have been proposed for wilderness classification by the Montana Wilderness Study Act of 1974. This Act provides for the study of these lands to determine their suitability for designation as wilderness in accordance with the Wilderness Preservation Act of 1964. The aforementioned land areas overlap considerably with roadless lands classified by the U.S. Forest Service; only those areas of non-overlap are shown on the Specially Managed Areas Map. Potential wild and scenic rivers have also been discussed in Section 5.2.1.

It should be realized that the amount of land which may potentially be classified as wilderness is finite and may never be increased; roadless areas which are opened to developments such as the routing of transmission line corridors may never be returned to the wilderness condition.

5.2.3. Land Ownership

The ownership of lands within the study area is shown on the Land Ownership map.

The study area includes parts of Lolo, Flathead, Lewis and Clark, Bitterroot, Beaverhead, Gallatin, Deer Lodge, Helena, and Custer National Forests which are administered through district offices of the U.S. Forest Service. The major portion of the forested land in the western and southern parts of the study area is included in these nine national forests.

Most of the other federal ownership, is administered by the Bureau of Land Management. The U.S. Fish and Wildlife Service manages the national wildlife refuges discussed earlier, and the U.S. Bureau of Reclamation administers a small amount of land.

Land of state ownership in the study area is primarily administered by the Department of State Lands. This non-forested land is generally scattered throughout the study area as a consequence of the Enabling Act, which granted the 16th and 36th sections of each township to the State of Montana. State forests are administered by the Department of Natural Resources and Conservation. The Fish and Game Commission controls game management areas, fish hatcheries, fishing access sites, state parks, monuments, and recreation areas. A small amount of state land is owned by the Department of Institutions, the Department of Agriculture, and colleges. Where large, continuous tracts of land are owned by the Forest Service, state lands are often clumped nearby as a result of land exchanges.

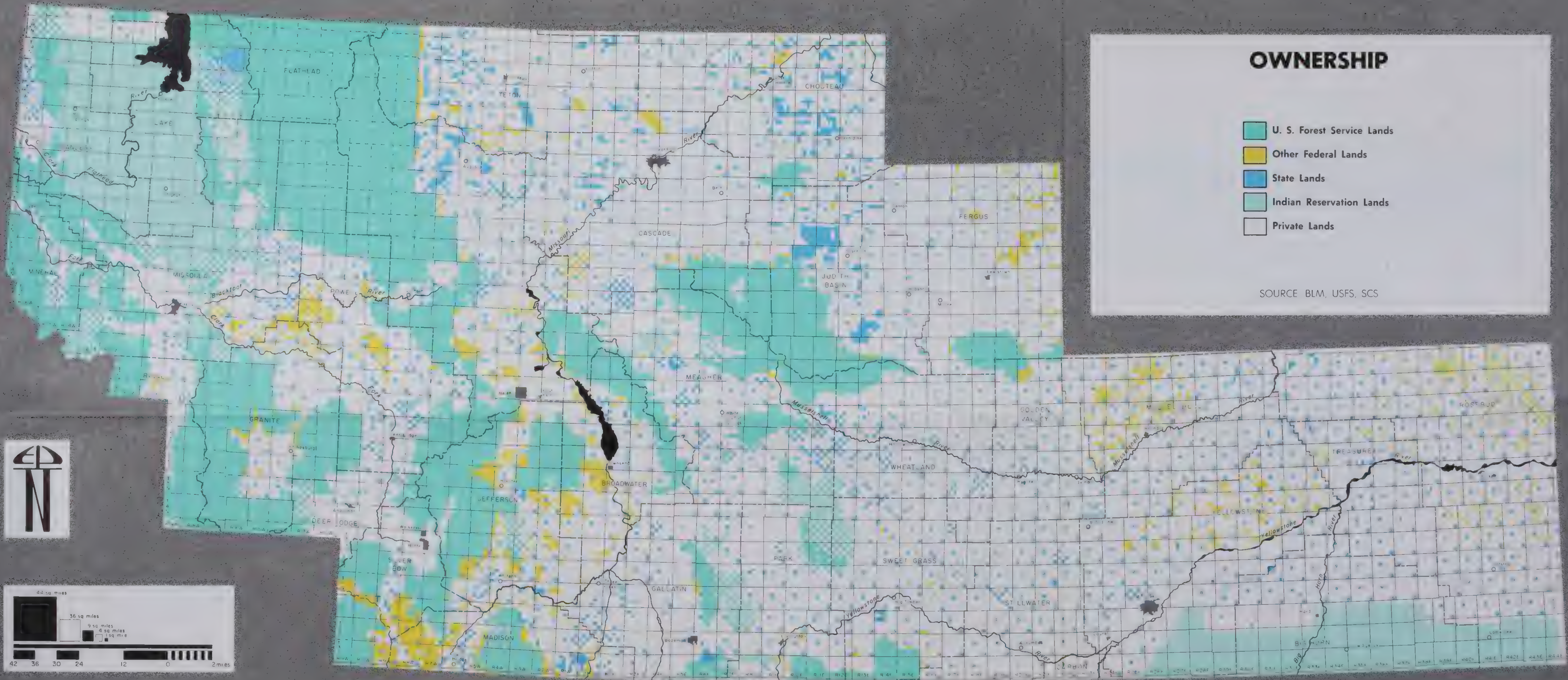
The major corporation owning land in the study area is Burlington-Northern. When railroads were first constructed in Montana, alternate sections of land along the railroad rights-of-way were granted to the railroad; a checkerboard pattern of Burlington Northern ownership is still evident in parts of the study area. Other corporations owning land are U.S. Plywood and Anaconda Copper and Mining.

Parts of three Indian reservations, the Flathead, Crow, and Northern Cheyenne, are included within the study area. Indian reservations include tribal land (controlled in part by the Bureau of Indian Affairs), private land opened to non-Indian settlement by the Dawes Act, and state-owned land.

The remainder of land in the study area is controlled by private firms and individuals. This is the predominant land ownership category except in areas where large tracts of land are owned by the Forest Service or Indian reservations.

5.2.3.1. Data Sources and Data Collection

The U.S. Forest Service provided National Forest maps at a scale of 1"=2 mi. showing Forest Service ownership for the entire study area as of



OWNERSHIP

- 🟩 U. S. Forest Service Lands
- 🟨 Other Federal Lands
- 🟦 State Lands
- 🟩 Indian Reservation Lands
- ⬜ Private Lands

SOURCE BLM, USFS, SCS

1974. The boundaries of Indian reservations were taken from the Bureau of Land Management (1967) map, "Areas of Administrative Responsibility of Federal lands", at a scale of 1:500,000. The Forestry Division, DNRC, also provided information on the location of state and corporate lands.

The locations of other state, federal, and private individual ownership were derived from a variety of sources. The Northwest Regional Planning Association land ownership map, at a scale of 1:250,000, provided information for several counties in the northwestern part of the study area. Updated land ownership maps prepared by the Soil Conservation Service at a scale of 1"= 2 mi. were available for several counties. For the remainder of the study area, BLM recreation maps at a scale of 1" = 2.5 mi. to 1" = 3.5 mi. were used.

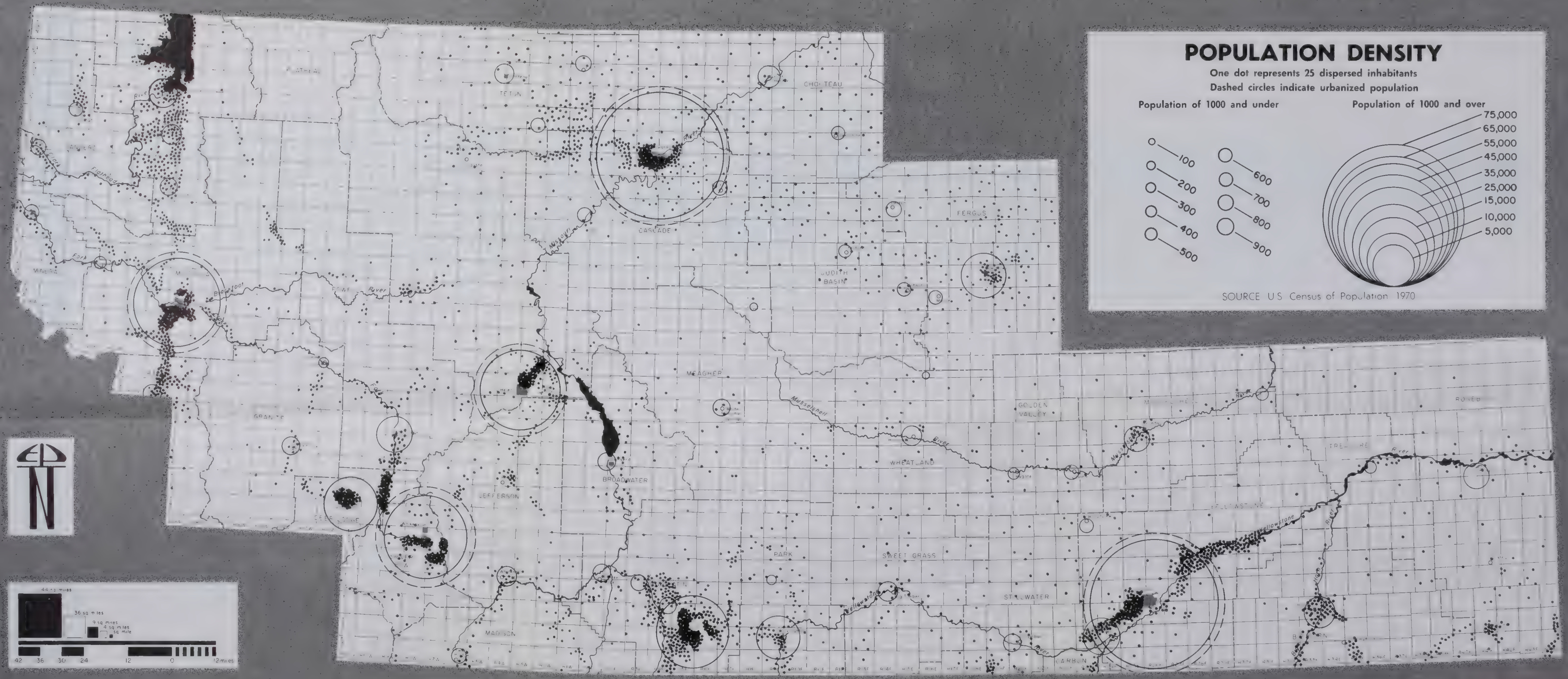
5.2.4. Population, Social and Economic Factors

5.2.4.1. Population

The transmission line study area extending from Colstrip in the east to Hot Springs in the west includes all or part of 34 Montana counties. The county populations range in size from 675 inhabitants in Petroleum county, where the population density is 0.4 persons per square mile, to 87,367 people in Yellowstone county, where the density is 33.1 persons per square mile (U.S. Dept. of Commerce 1970). Petroleum county exhibits the lowest population density in the study area, and Silver Bow county (population density 58.7 persons per square mile) the highest. Population is not evenly distributed throughout the study area nor within a given county (see Population Density Map). It is possible that a transmission line might cross or be located near highly populated areas even in counties in which the overall population density is low. The converse is also true. The applicants' preferred transmission route from Colstrip to Hot Springs illustrates these cases. Crossing the northern portion of Yellowstone county, the applicants' preferred corridor skirts the densely populated portion of the county stretching along the Yellowstone River from Laurel to Pompey's Pillar. In crossing a relatively short section of Lewis and Clark county the applicants' corridor passes within a few miles of the Helena city limits, although the actual area traversed is largely unpopulated. In Lake county the scattered residential patterns associated with small family farms could result in the transmission corridor crossing densely populated areas *vis a vis* other areas of the state.

5.2.4.2. Social Organization

The study area incorporates the diversity of Montana's social and economic structure. Land use patterns reflect these structures, with agricultural and forested lands covering most of the study area. Small communities, such as Broadview, Ryegate, Big Timber, White Sulphur Springs, Helmville, Ovando, St. Ignatius, Seeley Lake and Lincoln are scattered throughout the study area and function as service and commercial centers for the scattered agricultural population.



POPULATION DENSITY

One dot represents 25 dispersed inhabitants

Dashed circles indicate urbanized population

SOURCE U.S. Census of Population 1970

These small communities and rural areas tend to reflect a "gemeinschaft" form of social organization - that is, a social organization based on deeply personal, strong social bonds. Social solidarity is high as the people of the area share a similar set of rural values shaped by long association with one another and by sharing a similar life style and set of life circumstances. Integration into the community is usually a slow, gradual process and it is not uncommon for individuals to be classified as "newcomers" or "outsiders" even after living in the area for a number of years.

The larger, urbanized communities of the study area are predominantly located in the southern and western portions. Lewistown and Great Falls, located in the north-central portion of the state, are the most conspicuous exceptions. The economic bases of the urban areas vary. Billings is principally a service and commercial center (retailing) serving southeastern Montana and northeastern Wyoming. The communication, transportation, and utility industries are also major employers./1 Great Falls is also a major retailing center; manufacturing is its second largest industry group. Lewistown, Missoula, and Helena are retailing centers; higher education (University of Montana) is the second largest employer in Missoula, and public administration (principally state government) is the second-largest industry in Helena. In Bozeman, higher education (Montana State University) and retailing are the major employers. The Livingston economy is built on railroading and retailing. Butte relies on the mining operations of the Anaconda Company as its major employer; retailing is the second largest industry group. In Deer Lodge, public administration (state penitentiary and county government) and transportation (railroads) are the major industry groups. Anaconda has an economy built on manufacturing (Anaconda Company smelter) and health services (state hospitals at Galen and Warm Springs).

Social organization in the urbanized areas is more oriented toward "gesellschaft" - that is, social bonds are more contractual in nature. The individual lives in a less personal social system. Social interaction is governed more by law and contract than by tradition, and movement of persons, both soically and physically, is more open in urbanized "gesellschaft" situations. Integration of individuals into the community tends to be more rapid, since integration does not depend on developing deep, personal social bonds.

5.2.4.3. Social Services

Social services vary significantly throughout the study area. As a general rule, the larger the community, the more comprehensive are social service delivery systems. Social services increase in number, type, and size in the larger communities. In rural areas, police protection falls largely to the various county sheriffs' departments and to the State Highway Patrol. In the cities, police departments provide additional protection. Indian Police services operate on the Flathead, Crow, and Cheyenne reservations.

Rural areas and small towns have fire protection provided by volunteer fire departments. Various state and federal agencies such as the State Division of Forestry, Bureau of Land

Management, and Forest Service provide fire protection for grass and timber lands. In the larger cities, full-time, formally organized city fire departments care for areas inside the city limits.

Medical services are scattered throughout the study area. Four counties are without hospitals (Petroleum, Golden Valley, Treasure, and Judith Basin). Small hospitals are located in the county seats of the remaining, predominantly rural counties. Butte, Helena, Missoula, Billings, and Great Falls have relatively large portions of medical personnel and hospital services. Ambulance services are available in all counties of the study area, and air ambulances are available at the major urban centers. Services provided by county welfare agencies are available at the respective county seats of each county.

In the past 10 years, 21 counties in the study area have experienced population decline. In the rural counties, this decline has resulted in general pattern of excess school capacity. Two urban counties, Deer Lodge and Silver Bow, have also experienced population declines, but the closure of the local parochial school systems has greatly increased public school enrollments. Counties which have experienced population growth are generally finding school capacities adequate, with school enrollment growth matching increased populations. Housing is difficult to locate throughout the study area; the larger communities contain more housing opportunities than do rural areas.

5.2.4.4. Economic Factors

The study area runs from southeast Montana to the northwestern part of the state and includes a variety of landscapes and economic activity. The four major industrial centers of the state, Billings, Butte, Great Falls and Missoula all lie within the boundaries of the study area. The study area includes extensive agricultural acreage in the east and a large segment of the states' timber industry in the west. The general patterns of land use are more thoroughly described in Section 5.2.1.

Construction of large sections of the proposed transmission lines would necessarily be carried on far from any area trade centers. In such cases the local area would not be in a position to "capture" the potential markets represented by the well-paid construction crews. Most of the secondary economic effects would be gained by the few large trade centers of the region (Helena, Billings, Missoula, Butte, Great Falls, and Bozeman, depending upon the route).

Much of the economic impact of the transmission line will depend on the primary employment the line construction provides. Whether or not these jobs go to Montanans or to out-of-state labor depends heavily on the availability of in-state skills. Labor for right-of-way clearing should be available within the state. The International Brotherhood of Electrical Workers (IBEW) in Billings reported generally full employment conditions among their members in Montana as of mid-1973 (Westinghouse 1973). In a survey conducted in October 1974, Local 532 reported thirty job openings for electricians at Colstrip with no locally available electricians. It is on the basis of this labor supply situation that the majority of the line construction crews are expected to come from outside Montana.

FOOTNOTES

CHAPTER FIVE

1. The assessment of a community's economic base is drawn from Neil C. Gustafson, *Recent Trends/ Future Prospects: A Look at Upper Midwest Population Changes*, (Minneapolis, Minnesota; Upper Midwest Council, 1973).

CHAPTER SIX Impact Analysis

6.1. Natural Environment

6.1.1. Impacts on Geology

6.1.1.1. Physiography

The major environmental impacts of transmission line construction on physiographic features result from the cut and fill excavation necessary for access and preparation of tower sites.

The physiographic subdivisions described in Section 5.1.1. may be regrouped according to their excavational requirements, or "physiographic hazard". These are ranked on a scale of one to five, one representing essentially no impact created by access road construction and site leveling, and five representing extreme impact.

1. (Minimal impact.) Physiographic units A-1, B-1, P-1. No earth moving necessary. Minimal impacts with minimal constructional precautions.

2. Physiographic units B-2, P-4, P-6. Local stretches of road required, but can be minimized by careful road and tower siting. Relatively easy to locate good roads and tower sites.

3. Physiographic units F-4, A-2, P-2. Some difficult areas requiring continuous roads; occasional opportunities to minimize road construction by taking advantage of level terrain. Length of roads is approximately equal to length of lines. In A-2, wet alluvial lands, wheel ruts represent a special form of undesirable earth disturbance which may result in artificial water channelization and accompanying erosion.

4. Physiographic units M-2, M-3, P-5, F-1 At worst, this terrain is very bad, requiring continuous, lengthy roads and tower site leveling. However, with very careful siting and favorable circumstances, overall impacts could be reduced, for long stretches, to the level of 2. Overall, length of roads exceeds the length of transmission lines.

5. (Extreme impact.) Physiographic units M-1, M-4, M-5, F-3, P-3. Extensive, continuous road construction necessary, with length of roads much greater than the length of lines, frequently by a factor of two or more. Maximum depth and width of disturbed earth due to very steep hillsides. This extreme example is well illustrated by the access road along the 1973 MPC 230 KV transmission line across the Little Wolf Mountains, about 15 miles west of Colstrip.

6.1.1.2. Other Geologic Impacts

Geologic constraints upon transmission lines and potential impacts of them on geologic parameters are discussed below under three categories:

1. Construction impacts
2. Operational impacts
3. Impacts of physical presence of lines and towers

A. Construction Impacts

The most widespread and common impacts of transmission line construction result from earth-moving activity. Specific examples of these impacts include:

1. Soil removal and burial due to access road construction and tower site preparation;
2. Scarring of landscapes, and of specific geologic features that are of special human interest because of their scenic or intellectual value;
3. Inducement of hillslope mass failures; and
4. Disturbance of certain materials which complicate or preclude effective reclamation.

Road construction and site preparation require the greatest excavation; soil loss is greatest when these are undertaken on steep slopes. The total amount of soil area removed by cutting and buried by fill often exceeds the width of the road surface severalfold. The steeper the terrain, the wider the area of soil affected by road construction. Terrain that necessitates sharp bends in access roads at gullies, sharp, plunging ridges, and switchbacks, requires additional excavation for passage of large equipment and is therefore unfavorable for transmission line construction using conventional methods. These observations were considered in Section 6.1.1.1., Physiography

Because road building and site preparation cause the major adverse geologic impact of transmission line construction, the presence of existing secondary and unimproved roads, and ease of off-road travel, are significant environmental considerations. Logging areas, which generally contain good quality secondary roads, offer a distinct advantage over unroaded areas. The potential for most undesirable effects that result from earth moving can be minimized or eliminated by routing a transmission line corridor across the most level terrain, which requires least excavation or through areas already having roads.

Several construction activities may contribute to hillslope mass failures. Undercutting of slopes is the most common cause of landslides. Sensitive slopes may also be overloaded by the weight of the equipment. In one case at Pine Ridge, north of Hardin, apparently equipment vibration alone triggered collapse of a cliff face, narrowly missing the tractor operating below. Hillslope failure may also be induced by saturation that results from artificial ponding of surface runoff waters, although this may be prevented by proper construction practices.

The possible consequences of hillslope failure include: personal injury; damage to property; damming and siltation of streams; landscape scars; soil loss; and creation of undrained depressions which may be hazardous to livestock or promote further sliding. Even minor slope disturbances may create significant visual impact. For example, talus in western Montana is frequently blackened by slow-growing lichen. Even minor disturbance of the slopes, which reorients many of the rocks, creates a conspicuous, essentially permanent, light-colored scar.

Certain geologic terrains, frequently local in extent, are inherently unfavorable to revegetation of excavated sites. Areas of clinker, common in the eastern coal areas, where coal seams have burned in situ, may be nearly impossible to reclaim even with replacement of topsoil, due to the high permeability of the disturbed material. Similarly, in areas of existing shale badlands, excavation is likely to aggravate rapid erosion, preclude effective restoration, and make maintenance of access roads a continuous problem. In a large area of Precambrian shale (see Appendix K, Stratigraphy and Igneous Rocks) near the south end of the Big Belt Mountains, west of Ringling, lack of clay in either the soil or subsoil results in extreme erosion when vegetation is disturbed. Careful siting of access roads and tower sites or elaborate construction practices, such as the use of helicopters, may effectively eliminate many adverse geologic impacts.

B. Operational Impacts

Soil and other geologic materials contain clay, a material unique in its capacity to absorb large quantities of ions and water molecules onto the surfaces of individual clay particles. Weak electrostatic attraction among ions, water molecules, and clay particles plays a large part in determining the physical properties of some unconsolidated deposits. Electromagnetic fields surrounding A.C. transmission lines cause varying degrees of electrical induction in all nearby charged particles. If inductive redistribution of ions occurs in soil and regolith, then soil structure, slope stability, soil moisture chemistry, and groundwater quality may be affected. Since no information on these effects has been found, it is tentatively concluded that they are inconsequential.

C. Impacts of Physical Presence of Lines and Towers

An impact of the physical presence of transmission lines is that they may interfere with exploitation of geologic resources (see Appendix K, Economic Geology). At the least, the presence of transmission towers and lines in mining areas may cause inconvenience; at the extreme, the transmission facilities may preclude mining of some areas, and present a safety hazard to operation of large equipment. Existing mines, mining prospects which show potential for development in the near future, and oil and gas wells should be avoided by transmission lines.

Many of the geologic resources that occur as sedimentary units, particularly gravel, clay, limestone, and building stone, are widespread enough in occurrence that the amount of production precluded by transmission line towers is insignificant. Surface mining for some of these materials is presently being conducted within a number of BPA transmission corridors (USDI-BPA 1974). Transmission lines do not directly interfere with underground mining. New drilling for gas and oil is not affected because techniques exist for controlling the direction of the drill. Therefore, a drilling rig sitting some distance from the transmission line can drill into rock underlying the line.

Certain unique, well-displayed geologic features (included on the Recreation Map in Section 5.2.1.) provide significant insight into geologic processes or geologic history and occur on a scale such that this aesthetic appeal may be adversely affected by the presence of transmission lines or construction scars. It is important that transmission line corridors be located to avoid or minimize interference with such features.

6.1.2. Impacts on Hydrology

6.1.2.1. Surface Water

Forest clearing and devegetation affect volume and timing of stream discharge. Hornbeck et al. (1970) indicate that clearcutting and regrowth prevention by use of herbicides increased streamflow, mainly during the growing season, and caused higher summer peak flows and earlier spring runoff. Studies of clearcutting in several parts of the country have shown similar results without employment of herbicides. The increased runoff results from reduction of evapotranspiration and consequent soil water deficit (Hewlett and Helvey 1970) as well as possible other factors.

Forest clearing in areas of winter snow accumulation also increases the amount of total snow pack by eliminating loss resulting from interception and evaporation on tree limbs. The result is an increase in annual discharge. Timing and rate of meltwater contribution to streams depends on the microclimatic conditions prevailing within the cleared area. Hence, size of the cleared area, direction of slope, and elevation are critical factors. For these reasons, tree removal on or near snow survey courses affects snow accumulation.

Increased runoff may be beneficial from the standpoint of hydropower or irrigation. On the other hand, flood damage and increased soil and stream channel erosion could result. The impacts of clearing on runoff would be minimized if the transmission line corridor were routed through areas where least tree disturbance is necessary. The impact of a transmission corridor clearing on hydrology may be slight, relative to the impacts of other disturbances, such as urbanization and logging. However, some small watersheds may already be in such critical condition that any additional vegetation disturbance would be serious. These include severely burned basins and overdeveloped catchments. Municipal watersheds, one type of drainage basin where haphazard forest clearing and road construction is distinctly undesirable, are indicated on the Specially Managed Areas Map located in Section 5.2.1.

Numerous studies show that water temperature of streams is significantly increased when extensive shade vegetation is removed from the banks. Temperature change is inversely related to the discharge of the stream, and directly related to the increase in unshaded area (Brown 1970). Hence, it is imperative that transmission line corridors avoid small streams, neither running adjacent to them for significant distances, or frequently crossing meanders of streams.

Increased turbidity and siltation of surface waters resulting from removal of ground vegetation and topsoil disturbance are well known. Several studies (Megahan and Kidd 1972, and Frederiksen 1970) indicate that large increases in silt load of streams may result from road construction alone, and that this condition may persist for months or years afterward. Stream siltation is most severe locally, downstream from points where streams are forded by vehicles, and especially where bank excavation is performed.

Nutrient additions to surface waters may contribute to eutrophic processes. Areas devegetated through use of herbicides contribute significantly higher quantities of nutrients to area surface waters than undisturbed sites (Bormann et al. 1968). Clearcutting without use of herbicides results in smaller nutrient losses to streams than with herbicides (Marks and Bormann 1972). Nutrient transport is an invariable result of soil erosion; areas of greatest erosion potential are also the areas that may supply the most nutrients to surface waters (see Sediment Risk Map located in Section 6.1.3.).

Large lakes and reservoirs represent practical obstacles to transmission line construction. All rivers in the study area can be spanned by transmission lines at normal flow. However, the larger rivers, mainly east of the Continental Divide, such as the Missouri, Yellowstone, and Big Horn, have flood plains that are too wide to be crossed at every location with a single span. Transmission line towers on floodplains may cause pileups of ice and other debris during high spring runoff, possibly contributing to flooding or influencing rapid stream channel changes and bank erosion. Also, removal of trees from flood plains may increase flooding downstream, by removing resistance to flow. Channel changes may also be influenced by destruction of stablizing bank vegetation.

6.1.2.2. Groundwater

Floodplains and marshes where the water table is near the surface may not adequately support heavy wheeled traffic. The resulting ruts act as ditches which may alter the drainage of the area, causing erosion and increased sedimentation elsewhere. Wet areas such as Lake Basin, southeast of Broadview, become dry enough during the latter part of most summers for hay harvests. Deep ruts made in these areas during wet periods, unless restored, would interfere with movement of farm machinery.

In areas where the groundwater flows through thin colluvium that mantles bedrock slopes, intersection of the water table during road excavation may divert the groundwater to overland flow. Potential effects of this diversion include erosion of the road surface, interruption of springs and wells, and alteration of downslope ecosystems. The groundwater may also contribute to instability and slumping of the road cut and road bed. Where fault or fracture zones occur in bedrock, large quantities of groundwater and weakness of bedrock may aggravate these conditions, as along the existing road over Jocko Pass.

Groundwater recharge is affected by removal of vegetation, manifesting either a decrease or increase in recharge, due to accelerated runoff or increase in snow pack. Change in groundwater recharge may have positive or negative effects, depending on the local circumstances. Not knowing the specific circumstances, least disturbance of vegetation is favored. Ground water recharge rates and quality are affected by the same factors that affect surface water runoff (see the preceeding section on surface water).

Drilling for ground water is precluded beneath transmission lines. Likewise, maintenance of previously existing wells beneath transmission lines that requires drilling rigs or insertion of long pipes into the well is unsafe. Abandonment of the well may be necessary as a result. Except at tower footing and guy line anchor sites, transmission lines do not necessarily preclude the continued use of existing wells, although, for the most part, it should be possible to avoid wells by minor shifts in centerline location.

Significant limitations exist to accurately assess the potential for inducement of hillslope failures, and to completely identify areas where excavation of geologic materials may hinder effective restoration. Some areas where these hazards are known to exist or can reasonably be inferred are readily identified. These appear as dots on the Physiography Map. Some of these hazard areas are localized, and others are scattered over wide areas. Minimal surface excavation in the construction of roads and the use of helicopters greatly reduce these hazards, even in generally unfavorable terrain.

6.1.3. Impacts on Soil

The impact of transmission line construction, operation, and maintenance on the soil resource falls into two broad categories: preclusion of other land uses directly related to soil capabilities, especially timber production; and erosion resulting in lowered productivity of the site and sedimentation of surface waters. The impacts on land use are discussed in Section 6.2.1. This section will concentrate on impacts in the natural sphere, realizing that the natural and social spheres are integrated by man's activities.

There are four aspects of transmission lines that have an impact on soils:

1) Location and construction of tower foundations.

2) Location and construction of access roads, staging areas, storage areas, and the area around the foundation used during erection of the towers.

3) Permanent roads for maintenance and emergency repairs.

4) Electrical characteristics of the line (once operational).

A further consideration is the applicants' intent to restore impacted areas to as close to the original state as possible (Westinghouse 1973). Additional to the impact of transmission lines on soils are the constraints imposed on the lines by the soils. Both impacts are treated in the following discussion.

6.1.3.1. Construction Related Impacts

A. Right of Way

Soil properties must be considered in right-of-way selection. Rough, broken land for example, generally contains fragile, shallow soils that are unsuitable for transmission line right-of-ways due to the high costs associated with building roads in this terrain. Areas of hard, massive rock at or near the surface are also unsuitable for the same reason.

B. Tower Foundations

A further reason why hard, massive rock and rough, broken terrain are unsuitable for rights-of-way is the problem this material presents for excavating tower foundations. Rough terrain could also present problems in having enough work area around the tower foundation to erect tower structures.

Mass failure hazards, shrinking/swelling clays and high water table (especially where cold winter temperatures add the possibility of frost heaving) render a site unsuitable for tower foundations to varying degrees due to the effect on the stability of a site. These constraints can be overcome or at least mitigated by careful site selection, tower placement and construction methods, but varying amounts of cost and effort are involved. If these limitations are not fully recognized and corrected, off-site sedimentation of surface water could result.

Since the tower foundation itself does not cover a large area, the effect on site productivity is slight. However, construction and tower erection activity in the area surrounding the foundation can be significant. The effect on productivity and subsequent reclamation efforts will range from slight to severe depending on the revegetation potential of the soil disturbed. Off-site sediment risk caused by foundation construction impacts can be assessed much the same as for roads and staging areas.

C. Access Roads and Staging Areas

Access roads and staging areas present the most significant impacts on the soil resource as far as corridor selection is concerned. Construction of roads will disturb soil over the largest area and with the greatest severity, resulting in loss of productivity and off-site sedimentation of surface waters. Careful construction and location of roadways can minimize this impact in many areas. For instance, if roads are cut on contours and properly drained, and sediment traps are constructed based on terrain and season of use, long term erosion of the soil can be minimized. If, on the other hand, roads are located on the premise that "the straight line is the shortest distance between two towers," erosion of the soil will be a continuing problem. Staging areas have the same type of impact as roads.

Erosion has two main effects: on-site loss of topsoil and decline in fertility; and eroded soil transported to surface waters, thus lowering water quality. The likelihood of access roads and staging area construction and use generating sediment pollution of downslope surface waters is a function of:

1) The soil's inherent erosion potential;

2) Slope gradient;

3) Length of time the soil surface remains bare of protective vegetative cover; and

4) Proximity of the disturbed area to surface drainage channels. (Holdorf 1974; Kitchings et al. 1974; Donahue and Ashley 1973; and Schumm and Hadley 1961).

Long-term sedimentation risks can be mitigated by practices such as reseeding, drainage and location procedures which avoid erosive soils and surface drainage channels (Holdorf 1974; Packer 1967). The short-term risks during construction and shortly thereafter are largely unavoidable. Soil characteristics that limit suitability for roads and staging areas are those that limit revegetation potential for erosion control plantings and reclamation. Examples of these characteristics are low natural fertility of soils developing from material weathered from Boulder Batholith, poor tilth of some clay soils, which limits root development, and severe climatic conditions, as in alpine areas.

In level and gently sloping areas where cut and fill road construction might not be necessary, (Westinghouse 1973) trafficability of the soil is important. This is a measure of the load bearing strength of the soil, i.e., how well the soil can resist compaction and reduction in soil can resist compaction and reduction in natural infiltration rates, permeability and structural aggregation. Low trafficability, relative to intensity and season of use, would result in erosion and associated sedimentation risk, and loss of site productivity.

6.1.3.2. Operation Related Impacts

A. Electrostatic, Electrochemical and Heat

The impact of the electrical characteristics of an operating line on the soil immediately under and around the line have not been identified (DNRC, Soil Group Workshop 1974b). Some possible interactions are:

1) Effects on the soil molecular system, e.g. cation exchange capacity, clay properties, etc.;

2) Effects on soil microorganisms;

3) Effects of noxious gases produced by the line (if any) on erosion control plantings (e.g. ozone, nitrogen oxides; cf. Section 6.1.4.).

4) Effects on the soil water regime and resulting effects on erosion control plantings and long term site reclamation efforts.

Further research must be conducted prior to making any definitive statements on the nature and extent of impacts on the soil research by an operating transmission line. The framework for this research should also include impacts on the microclimate around the line and resulting impacts on vegetation in terms of erosion control and site reclamation.

6.1.3.3. Maintenance

The roads needed for maintenance and emergency repairs, after initial construction, shall be stabilized, drained and reseeded (Westinghouse 1973). The most important consideration for soils is the season of use and the type of equipment used. Movement of heavy equipment through mountainous areas during the spring runoff period can be regarded as an extreme but realistic possibility which would have a tremendous erosion impact in some areas.

6.1.3.4. Reclamation

Reclamation depends on the ability to limit erosion during construction and control and minimize erosion after construction. This can be accomplished by careful consideration of all the above limitations and attempts to disturb soil as little as possible during the construction phases, with particular attention to limitations on revegetation potential.

6.1.3.5. Impacts of Significance in Corridor Selection

Soil disturbance is greatest in the construction of roads, the staging and storage areas and the immediate vicinity of the tower foundations during the tower erection and conductor stringing operations. This disturbance is primarily due to vehicular traffic and, where necessary, cut and fill road construction. All lands with slopes in excess of 4% usually require cut and fill road construction. Potentially, this is most of the study area. Natural vegetation will be destroyed during construction activities, although an attempt will be made to preserve the existing low-level vegetation on gently sloping lands. Whether or not this can be accomplished will depend on traffic intensities (including the weight of the equipment) and soil conditions during use (Westinghouse 1973).

Vehicle traffic compacts the surface horizons, greatly reducing the soil's natural infiltration rates and permeability and generally weakening or destroying the soil's aggregates. The gravel and stone content of the exposed horizons then becomes the determining factor in the erodability of the soil (Holdorf 1974; Packer 1967). Material such as these coarse fragments resists detachment and movement and lowers the erodability of the soil. The erosion hazard for compacted soils differs from that of cultivated soil since other soil properties, i.e., water holding capacity, permeability, etc., are reduced to a common level by the compaction. Thus, varying climatic factors are of lesser importance since any amount of precipitation will yield runoff due to the lowered soil permeability.

The following factors were considered in assessing the impact of transmission lines on the soil resource.

1) Compacted soil erosion hazard, as indicated by the percentage of coarse fragments in the exposed horizons;

2) Limitations on revegetation potential: climatic, fertility, saline/sodic soils, poor tilth, etc.;

3) Drainage density pattern of the landform as it effects the probability of eroded material entering the surface drainage system;

4) Average slope gradient as it determines necessity of cut and fill construction and limits soil development. (Holdorf 1974).

The inventory map (based on the Ecoclass system) mentioned in Section 5.1.3.2. resulted in distinct units each of which were evaluated in terms of the four parameters listed above. Each map unit was subsequently given a sediment risk rating of severe, moderate or slight. The resulting Sediment Risk Map shows groupings of areas of similiar hazard ratings, although the critical factors causing the hazard rating may not have been the same even in adjacent units. This map was further refined by incorporations of field data, especially where field observation identified a local inclusion that warranted a more severe rating than the larger unit in which it appeared.

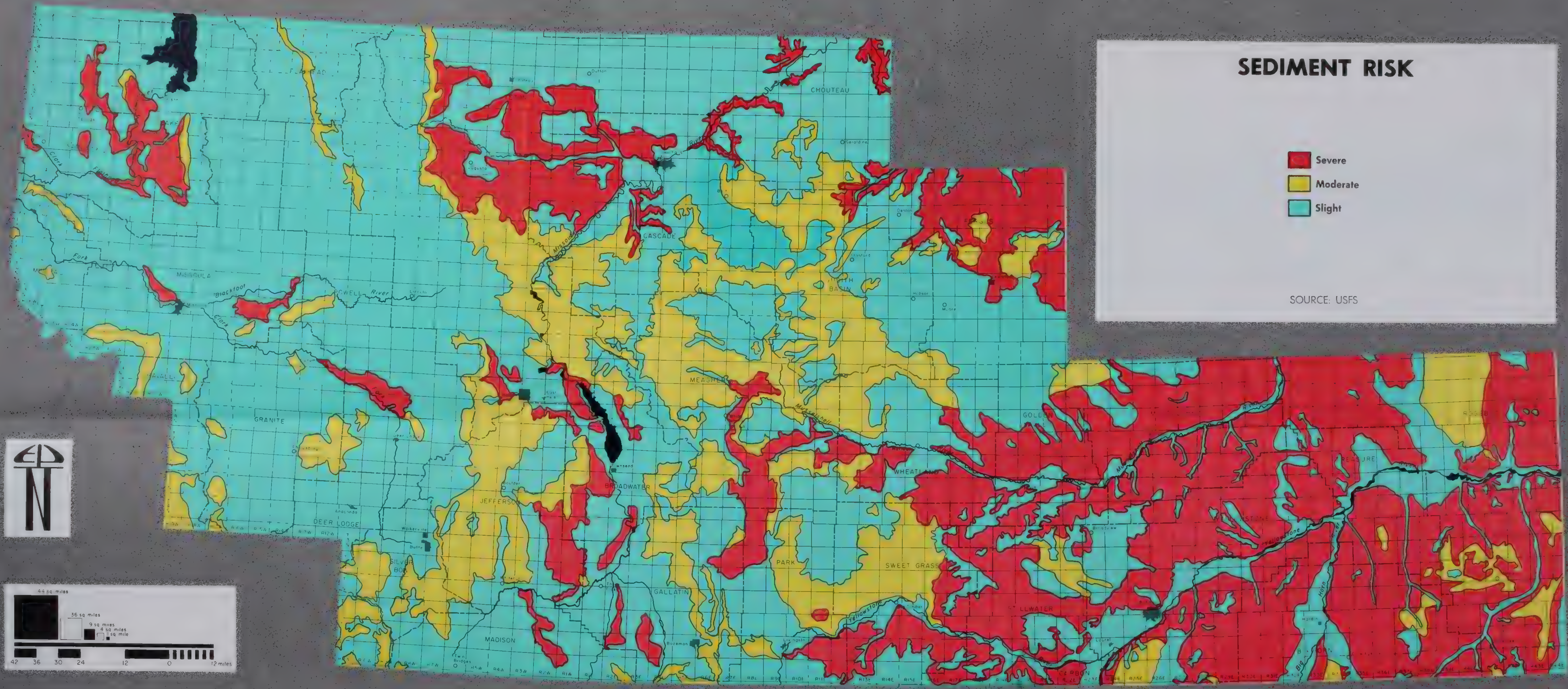
6.1.3.6. Sediment Risk Map Ratings Defined

A. Slight

Areas rated as "slight" range from relatively free of potential erosion hazards to hazards that are easily overcome at little or no extra cost. An example is the mountain soils west of the continental divide on consolidated bedrock. There is sufficient coarse fragments material in the profile that gives the soil cohesion and bearing strength so compaction doesn't present an erosion hazard. Moisture and other climatic factors, and relatively fertile soil present no limitations to reseeding a vegetative cover. Surface drainage (low order stream density) is not a factor as most drainage is subsurface. The result, in spite of high relief, is only a slight sediment risk.

B. Moderate

A moderate rating is given to areas where potentially significant erosion hazards occur that can be overcome with proper design and construction methods. Cost would certainly increase, but not to any extreme degree. An example of a unit with a moderate rating is the rolling shale uplands in eastern Montana. These are generally shallow soils underlain by soft shales. They have almost no gravel or cobble in the profile, and their clayey texture presents a severe erosion hazard when compacted. This clayey texture results in poor tilth and limits reseeding of an erosion control plant cover, but because these soils occur in a higher precipitation zone (14-20 inches using criteria developed


SEDIMENT RISK
Severe
Moderate
Slight
SOURCE: USFS
FLATHEAD
CHOUTEAU
CASCADE
MISSOULA
JUDITH BASIN
MEAGHER
GRANITE
JEFFERSON
BROADWATER
DEER LODGE
SILVER BOW
GALLATIN
MADISON
PARK
SWEET GRASS
WHEATLAND
GOLDEN
TREASURE
LLWATER
CARBON
BIG HORN
Missouri
Blackfoot
Clark Fork
Powell River
Musselshell
Yellowstone
Big Horn
N
44 sq miles
36 sq miles
9 sq miles
4 sq miles
1 sq mile
42 36 30 24 12 0 12 miles

by the SCS for range management evaluation) the overall limitation on revegetation potential is only moderate. Low order stream density is also rated as moderate and thus, the overall rating for sediment risk in this unit is moderate.

C. Severe

Units with severe rating are those with a high probability of sediment pollution of surface waters resulting from disturbances to the soil mantle. Many of these hazards can be minimized by very careful design, location and construction techniques, but with high cost. In some units the only way to avoid sediment risk is to avoid the unit. An example of a unit with a severe rating is the rolling shale uplands of eastearn Montana in the lower precipitation zone (10-14 inches, SCS criteria). The compacted soil erosion hazard is severe and there are no coarse fragments in the profile to resist detachment and movement. The soils are shallow, sometimes with outcroppings of soft shale bedrock. The clayey texture of the soils developing from this soft shale parent material results in poor tilth and limits the potential for revegetation. Poor tilth in addition to the lower rainfall (which often comes in short periods of time so the effective rainfall for vegetation is even lower than the actual average) requires a severe rating for limitations to erosion control plantings. This well dissected unit has a relatively dense surface drainage pattern with the soil remaining bare for long periods of time. The soil is susceptible to erosion and there is high probability that sediment will move into the surface drainage channels. The overall rating of the unit is severe.

6.1.4. Impacts on Vegetation

The impacts of the proposed transmission line on vegetation vary with vegetation type, physiography, adherence to environmental guidelines, and other factors. The applicants have indicated that strict environmental guidelines will be followed (Westinghouse 1973). The following impact assessment is based on that assumption; however, less-than ideal situations that could conceivably occur will be addressed.

Both positive and negative effects of transmission line construction, operation, and maintenance will be discussed. The literature on possible effects of EHV transmission is scanty, especially for Montana. That a given impact is not mentioned in this impact statement should not be taken as evidence that there would be no such impact; future research may prove otherwise.

Effects and impacts will be mentioned only if there is supportive literature, if they have been demonstrated by past experience, or if they are intuitively obvious.

6.1.4.1. Construction Phase

A. Vegetation Removal

The removal of vegetation from transmission line right-of-way corridors, access roads, and other areas such as concrete batch plants and staging areas cannot be avoided in most cases. Forested areas usually present the most severe problems of vegetation removal. In order to accommodate the large, heavy equipment needed to construct the lines, new access roads must be wider than normal forest roads, and existing roads generally have to be widened and upgraded considerably (Yeager 1973). The corridor must also be cleared to the extent that any equipment used within its limits is able to move easily and safely.

To determine the intensity of the impacts of vegetation clearing, the method of removal must be considered. Hand clearing and slash disposal of trees and brush has less impact than mechanical methods. A great deal of site disturbance results when dozers are used to clear and pile logging slash and brush. However, the discussion here will be limited specifically to impacts of vegetation removal. Although impacts of vegetation removal on range land may not be as extensive, they are ecologically as great.

The first stage of the construction phase is line surveying and staking. The impacts of this operation on vegetation result from driving motor vehicles off main access roads and from excessive clearing along the survey line (Yeager 1973). If vehicles are driven cross-country in areas where vegetation or the ecosystem in general is very sensitive to such use, such as alpine grassland, subalpine forest, or forest type with shallow rocky soils, the time required for recovery may be great. In the eastern part of the study area, badlands, on which vegetation cover is specialized and sparse, is probably the most sensitive area.

Clearing of the survey line normally varies in width, but would not cause substantial adverse impacts. However, it is possible that a change in location of the line could be made, in which case there would be unnecessary damage to vegetation along the abandoned line. Also, if the initial survey line were not excessively cleared, impacts would be minimized. The impact of this damage could range from minimal damage to severe, depending on the extent of clearing. Also, trees and shrubs cut and left lying on the ground pose a risk of Ips beetle (Ips pini) and bark beetle (Dendroctonus spp.) infestation, which could spread to adjacent areas.

The clearing and road building phase of construction causes the most severe impacts to vegetation. In the western third of the study area, the topography is rough and in many places very steep. Due to this and to the predominance of tree cover, there are impacts of the environment on the transmission line as well as impacts of the transmission line on the environment.

The greatest impact of the environment on the construction of the line is the extra time the contractors must spend on construction of roads in steep terrain, movement of heavy equipment for clearing tower sites, and construction of towers. The amount of clearing to be done will affect the progress of construction.

The same environmental factors which impact the construction are impacted by construction. The construction of excessive amounts of road in mountainous terrain causes extensive soil nutrient and biomass production losses through soil erosion (Kitchings et al. 1974). All but the main access roads would be revegetated, and thus the impacts on these sites would not be permanent; however, a considerable amount of time would be required to stabilize and eventually return the sites to productive forests.

Along the right-of-way vegetation cover must be cleared; all trees that would interfere with conductors or the installation of conductors and towers could be removed. Nutrient loss would not be as great as that caused by road construction, but would still be an important impact. Tower sites, staging areas, materials storage, and concrete batch plant areas would be cleared and subjected to extensive equipment traffic. Tower sites, approximately 150 sq.ft. (Yeager 1973), could possibly be cleared to bare mineral soil, especially on steep slopes. Heavy equipment concentrations in foundation site, staging and other areas would also effectively remove vegetation down to bare mineral soil. In all areas where this occurs, nutrient losses can be significant.

Vehicles and heavy equipment used off specified roads must be prohibited, since such action increases damage to vegetation.

Loss of forest biomass along the right-of-way is extensive, because trees are not allowed to grow back. On national forest land, the right-of-way is extensive, because trees are not allowed to grow back. The right-of-way is taken out of timber production, an action which will consequently affect the annual allowable cut of the forests involved.

Rangeland vegetation types of central and eastern Montana do not exhibit the life form diversity that occurs on forest land. For this reason the impact of transmission line construction on rangeland is not as severe. Vegetation removal need occur only on access roads and tower sites. The impacts of such actions are basically the same as on forested lands, but on a smaller scale.

The greatest impact on rangeland is caused by the actual installation of the towers and conductors. The tendency for cross-country vehicle travel on rangeland is greater than on forest land because the lower-growing vegetation presents few barriers to such travel. Besides impacts of cross-country travel discussed earlier, range condition and production could be decreased as a result of it. For example, an area presently bordering between a fair and poor condition class could be pushed into the poor class due to vegetation disturbance from cross-country vehicle travel.

Riparian (stream bank) vegetation is very sensitive to disturbance. Right-of-way and access roads are certain to cross or parallel water courses at some point. Partial removal of riparian vegetation can have serious impacts on water quality and stream channel condition, and consequently on vegetation upstream and downstream and downstream from the disturbed site.

Total removal of stream bank vegetation in the right-of-way is certain to cause the above described impacts because the stability of the bank would be lost. If this situation exists over a large area or at a critical point along the stream, large portions of the stream bank could be dislodged, thus increasing the risk of flooding in spring and fall, which could have a further effect on adjacent vegetation communities.

B. Associated Impacts of Construction

1. Nutrient Losses

With the removal of vegetation from steep slopes with shallow soils, an increase in erosion potential will occur, thus increasing the potential for nutrient loss. Runoff water from heavy rains can carry away the top layer of soil, including partially decomposed organic matter rich in nutrients.

Nutrient loss can also occur on relatively level areas where clearing on mineral soil has occurred. Nutrients can be leached from the soil profile out of reach of roots. This happens as a result of removal of duff material (buffer material) which acts to slow down water infiltration through the soil. Soil structure and texture also determine the rate at which water can move through the soil. Underground water systems can also effectively move leached nutrients further from the area (Buckman and Brady 1969).With the reduction of available nutrients for plant growth, plants adjacent to disturbed areas could suffer a decrease in vigor and consequently be more susceptible to further damage.

Possible destinations of nutrients leached from the soil are streams, rivers, ponds, and lakes, where they would be available for use by aquatic vegetation, ultimately resulting in eutrophication activity.

2. Dust

During the summer months dust is a problem. Due to the size and weight of construction vehicles and equipment, and the speeds at which they travel, access roads are broken down easily and produce considerable amounts of dust. This dust will cover nearby vegetation and could cause a reduction in photosynthetic activity through blockage of leaf stomatal openings, by which the plant participates in carbon dioxide gas exchange. The net result may be a decrease in total biomass and hence in forage production.

3. Insect Infestations

Vegetation removal, particularly in forest, could cause insect infestations if slash is not properly disposed of.

In the ponderosa pine zone the Ips beetle and mountain pine beetle (Dendroctonus ponderosa poses a threat to ponderosa pine, lodgepole pine, and Douglas fir in much of the forested areas within the study area (McGregor and Williams 1973). The Douglas fir beetle (Dendroctonus pseudotsugae) is also present in some national forests within the study area, thus posing a threat to Douglas fir stands.

With removal of forest cover on right-of-ways, trees along the edges are often damaged. Because of this, and because of improper slash disposal, outbreaks of insect populations could occur. These insects breed in the slash and weakened trees, and as their populations increase, they move into adjacent stands and can effectively destroy large tracts of timber.

4. Poisonous and Noxious Plants

In general, undesirable plants seldom invade a well-established native vegetation stand. The succession of plant species in disturbed areas depends on the available seed source and the ability of species to compete for existing moisture and nutrients. In areas where a seed source of undesirable plant species exists, extreme caution should be used in construction and maintenance practices to avoid disturbance of natural vegetation and exposure of mineral soil. Many noxious plants are highly competitive and readily move into disturbed sites. Since disturbed soils cannot be stabilized by a permanent cover in a short time (Morris and Meuchel 1956), sound construction and maintenance practices are required to prevent invasion of undesirable plants.

6.1.4.2. Operation

A. Corona Effects

Corona dishcarge from electric transmission lines is known to result in electrochemical oxidants. The most signficiant ones are ozone (O_3) and nitric oxides (NO_x) (Zabrosky and Rittenhouse 1954; Scherer, Ware and Shih 1972). The amount of toxic gases produced is gencrally greater with higher voltage lines (500-765 KV).

The threshold level, for vegetation injury varies with species and even within species, but in general, for the most sensitive plants, it is from 0.05 to 0.12 parts per million (ppm) for 2-4 hours exposure to ozone (Hill et al. 1970). The response or injury sustained by a given dosage also varies by stage of plant growth, nutrition, light intensity, relative humidity, and temperature.

Measurements made under dual 500 KV lines at Oak Ridge, Tennessee revealed ozone concentrations of 0.18 to 0.21 ppm (Auerbach et al. 1973).The exposure time for this test is not known. The background ambient ozone measurements have been subtracted from this and all other values reported. These abnormally high levels were attributed to moderate temperature inversions near mountains. This same type of situation could occur in Montana, especially in winter. Ozone concentrations at the same location at a later date were only 0.02 to 0.03 ppm. These measurements were taken at the edge and center of the rights-of-way of dual 500 KV lines between 9:00 and 10:00 a.m. Measurements made after 12:00 p.m. have shown higher concentrations presumably because ozone increases with increased light intensity.

In another study made under dual 500 KV lines at Oak Ridge, between 0.001 and 0.002 ppm of ozone have been measured (Kitchings et al. 1974). "However, the deleterious effects on - plants directly beneath the lines and adjacent to the corridors, which could be affected by chronic exposure to ozone drift have not been identified" (Kitchings et al. 1974 p. 62).

The plant species most sensitive to ozone are Bel W3 tobacco (0.035 ppm) and pinto bean (Heck et al. 1965). Heck, Dunning, and Hindawi (1965) found that the threshold of injury from ozone varied from day to day at the same location and also from one area to another. Their research indicates that the general vegetation injury threshold is 0.03 ppm for four hours of sustained exposure.

In general, vegetation exhibiting visible ozone injury has small necrotic spots or flecks on the upper leaf surfaces. Palisale cells collapse, and if the ozone concentrations are sufficiently high, upper-epidermis cells collapse. The cell collapse results in sunken areas and possible lesions (Hill et al 1970). Ponderosa pine subjected to chronic ozone exhibits chlorotic needle mottle symptoms that develop from the tip to the needle base. Eventually these symptoms are followed by necrotic tip tieback. Since ozone primarily attacks the more mature needles, affected trees only show recent one year-old needles (Hill et al. 1970).

The synergistic effect of ozone (O_3) combined with sulfur dioxide (SO_2) produces injury to plants at lower concentration levels than the levels of each acting alone. Menser and Heggestad (1966) found that Bel W3 and Bel-B tobacco were injured at 0.028 ppm O_3 plus 0.28 ppm SO_2 for two to four hour exposures. Studies by Tingey et al. (1973), however, indicate that O_3 concentration must be at least 0.05 ppm to produce synergistic effect with SO_2 for sensitive plants. Jaeger and Banfield (1970) documented synergistic effect at 0.05 ppm O_3 with 0.05 ppm SO_2 in 12 hours exposure on eastern white pine (Pinus strobus). The above studies indicate that it is unrealistic to say that a given concentration of ozone will not cause damage to vegetation. Research is needed, especially in local areas, to determine what concentration levels will injure native and crop vegetation under various environmental conditions. For example, it is conceivable in Montana that a synergistic effect of O_3 and SO_2 could occur in surrounding areas of Billings, East Helena, Butte, Anaconda, and Missoula that have SO_2 in the atmosphere.

Study area tree species most sensitive to ozone are ponderosa pine, box elder, quaking aspen and green ash (USFS 1973). Sensitive crops include alfalfa, barley, oats, beans, rye, sweet corn, and wheat. Other sensitive vegetation includes snowberry and lilac (Hill et al. 1970).

Nitrogen dioxide (NO_2), one of the nitric oxides, acting alone will injure vegetation if concentration levels approach 2.5 ppm for four hours of sustained exposure (Taylor 1967). In another experiment, Taylor and MacLean (1970) found that very sensitive species, such as pinto bean and tomato, may be injured at 6 ppm of NO_2 for only a two-hour exposure. Presently, there is no documented evidence that there is a synergistic effect of NO_2 and O_3. In the study area, the only known plant that has intermediate toxic sensitivity to NO_2 is rye.

Although this discussion has centered on known threshold concentrations of the two most significant toxic chemicals produced by transmission lines, it is believed that photosynthetic activity and growth are adversely affected at lower levels than the threshold concentrations (Treshow 1965). For example, Darley and Middleton

(1966) state that less than 1 ppm of NO_2 affects plant growth.

Work done by Taylor, Dugger, Thomas and Thompson (1961) with citrus trees, and a study by Miller, Parmeter, Flick and Martinez (1969) with ponderosa pine seedlings, indicates that low concentrations of ozone also suppress growth. This may result from an abnormal increase in respiration (Barnes 1972).

Periods of high concentrations of ozone (as much as .04 to .07 ppm--Shah 1974a) caused by high corona loss during inclement weather or temperature inversions could conceivably result in a shift in plant community composition. Harvard (1971) found in Utah that plants sensitive to ozone (.15-.30 ppm for three hours) were eventually dominated by more tolerant species. Miller (1971) reports in California that ponderosa pine was eventually replaced by less desirable shrub species.

B. Electromagnetic Field and Electrostatic Induction

The effect of electromagnetic fields on vegetation is obscure. The possibility of the magnetic field interfering with the movement of nutrients has not been documented. Seed germination may even be helped by passing the seeds through a magnetic field prior to planting.

Evidence from the eastern United States indicates that some plants cannot grow under transmission lines (Shah 1974b). This phenomenon may be the result of electrostatic induction or the presence of electrochemical oxidants. Electro-coupling (Section 4.2.4.) may occur with some trees; it is reported that current has passed through trees in the northeastern United States, causing them to dry out.

The possibility that current from 500 KV transmission lines may pass through trees and ignite grass and shrubs under the line has not been ruled out (Anon. 1974).

6.1.4.3. Maintenance

Maintenance of the transmission line and the right-of-way after construction is completed can have impacts on vegetation. To have the least constraint on transmission line operation and maintenance, vegetation on a transmission line right-of-way should be stabilized and low--growing. However, a plant community of this description is unlikely to develop naturally if the original vegetation, before right-of-way clearing, was stabilized, but not low-growing, such as a forest. In such areas, some method of cutting back or suppressing the vegetation would have to be employed to develop a low-growing community over an extended period of time.

The two methods most likely to be employed to accomplish this are mechanical cutting of vegetation and use of herbicides. Mechanical methods of cutting vegetation to keep it away from conductors and provide access for maintenance crews would have impacts similar to (but lesser in magnitude than) those resulting from vegetation removal in the construction phase.

The use of herbicides in addition to strip clear-cutting done during construction can increase levels of nutrient loss above those observed with strip clear-cutting alone (Bormann et al. 1968). Under such a system of cutting and subsequent suppression, available nutrients are lost due to increasing water yields and thus a reduction occurs in the ecosystem's ability to extract nutrients from the leaching water (Kitchings et al. 1974). If herbicides are not used, and successional stage species are allowed to grow and develop, nutrient losses can be minimized by:

> 1) Channelling of water from run off to evapotranspiration, thereby reducing erosion and nutrient loss; 2) reduction in rates of decomposition through moderation of the microclimate during the growing season, so that the supply of soluble ions available for loss in drainage water is reduced; 3) simultaneous incorporation into the rapidly developing biomass (of successional vegetation) of nutrients that do become available and that otherwise might be lost from the system. (Marks and Bormann 1972, p. 24).

A. Revegetation

Since revegetation of right-of-way corridors to original vegetation communities is difficult and in some cases impossible, a monoculture (single species population) is often established. Without species diversity, wildlife habitat is reduced, and the vegetation could be subjected to species-specific insect infestations. Examples of monocultures often established in right-of-ways are Christmas tree plantations in forest types and crested wheatgrass on range types.

Revegetation should be restricted to native plant species whenever possible, since introduced species are often very hardy and able to adapt to a wide variety of ecological conditions. For this reason, they are competitive with natural species and, in many instances, are capable of moving out of the right-of-way and replacing native vegetation. Whenever native vegetation is undesirable for revegetation work, species having forage value for wildlife and livestock, such as those recommended for Montana in The Interagency Forage, Conservation and Wildlife Handbook should be used (Cooper 1973). Examples of these species are: little bluestem, Kentucky bluegrass, bluebunch wheatgrass, sweetclover, silver sagebrush, and greasewood.

If revegetation work is done carefully, a relatively dense shrub community could increase browse production and cover for wildlife species (Tabor et al. 1973).

B. Associated Impact of Maintenance

1. Herbicides

When herbicides are used, they can affect vegetation outside the target areas. Drift of spray or volatile fumes via air currents from target areas to adjacent vegetation, and surface as well as underground watercourses, can be a definite hazard causing crop damage or loss (Westlake and Gunther 1965). Also, herbicides reaching watercourses will kill aquatic life and eventually predators (consumers) of aquatic life. Rainfall can also act as an agent for transport of herbicides to areas remote from the site of application (Cohen and Pinkerton 1965). Though unnecessary damage to vegetation outside the corridor can be significant, strict adherence to environmental standards for herbicide use can minimize this impact (Kitchings et al. 1974). Some of the factors that influence herbicide drift direction, distance, and amount are droplet size, direction and velocity of wind, and type of spray used (Anon. 1968).

2. Insecticides

In simplified or monotypic communities, the use of chemical insecticides may be necessary to control insect outbreaks because natural predators do not usually occur in a monoculture (Kitchings et al. 1974).

Insecticides can be transported from target to non-target terrestrial and aquatic communities in the same ways that herbicides are transported. Some insecticides are persistent, and consequently are subject to biological magnification through food chains. This may impair health and cause eventual death to wildlife species, especially those species which are members of higher trophic levels such as raptorial birds and other predators (Rudd 1964).

6.1.5. Impacts on Wildlife and Fisheries

Several negative effects of overhead electric power transmission on wildlife are well documented, and others are suspected. Some positive effects are also known, and are likewise explained below.

6.1.5.1. Construction Period

Vegetation damage, stream siltation and watershed erosion during the construction period are discussed in other sections, but is noteworthy that mechanical injury to the environment will have repercussions on the fauna. Many of the vertebrates would be temporarily displaced during the construction period. They might return after the line is installed, but the rate of return and subsequent densities are unknown.

The presence within a previously roadless area of heavy equipment, vehicles, and people associated with construction would drive those species which are intolerant of human activity, such as the grizzly bear, wolf, and, to a lesser extent, elk, black bear, and mountain lion, from the area.

Vegetation damage and/or removal during construction may be particularly detrimental to certain game species such as sage grouse and antelope. The removal of large areas of big sagebrush which antelope use for food and sage grouse use for food and cover would permanently reduce the carrying capacity of the affected areas for these species. Also, the removal of tree cover and certain shrubs (i.e., skunkbush) would be detrimental to mule deer and turkey populations.

If construction operations occur during the nesting season, some nests will be destroyed and others abandoned. This factor is most important for birds (such as raptors) which are relatively uncommon or for which nesting habitat is limited. Raptorial birds are more prone to abandon nests prior to hatching time, so to minimize this hazard, construction in forested areas should be forestalled from April 1 through June 15, and raptor nest cliffs in all habitats should be avoided by a mile-wide buffer zone. The corridor and access roads should also avoid elk calving areas, especially where the available habitat is limited.

1. Construction On or Near Streams

Construction across streams should be discontinued during spawning periods (spring for rainbow and cutthroat, and fall for brown, brook and Dolly Varden trout). Rivers and streams should be crossed near existing bridges if at all possible. All efforts should be made to reduce siltation, which is one of the most important factors limiting natural reproduction of salmonids in streams (Cordone and Kelley 1961).

6.1.5.2. Positive Effects

Deforestation of a swath through forested areas may have long-term effects on wildlife. Lay (1938) found that woodland clearings had 41% more bird species and 95% more individual birds than woodland interiors. Egler (1953, 1957) found that cleared areas produce more food for some game species. These studies suggest that the ecotone created by opening a swath in the forest may have a positive effect on some wildlife species if they are not otherwise deterred by the presence of a transmission line.

Washington and Oregon have several existing 500 KV transmission lines, and both states have significant elk and deer populations. In the absence of quantitative data, wildlife biologists in those states report no obvious negative effects of the lines on any wildlife species, but rather that some deer and elk are foraging in those power line corridors where plant foods have not been eliminated by herbicides (White, Ebert, Mericle, Parsons and Lockhart 1974).

Tabor et al. (1973) reports heavy use of a transmission line right-of-way in the Cedar River area in Washington by deer and elk. Brown (1974) reports that mule deer, bighorn sheep and elk are crossing under, feeding, and bedding near the only energized 500 KV line in Montana (Dworshak to Hot Springs).

In areas where suitable trees and cliffs are unavailable, raptorial birds, ravens (*Corvus corax*) and magpies (*Pica pica*) would probably nest on the power line derricks. Nelson (1974) reported golden eagle (*Aquila chrysaetos*), osprey (*Pandion haliaetus*), raven, red-tailed hawk (*Buteo jamaicensis*), and ferruginous hawk (*Buteo regalis*) nests on transmission line towers (34.5 KV to 230 KV) in western Idaho. Raptors also nest on 500 KV lines. Active raven and red-tailed hawk nests were observed on 500 KV towers in Washington and Oregon.

This potential positive effect of increasing raptor productivity may be offset by the increased mortality to eggs and young due to nests blowing from towers and overheating of the young reared on the sun-exposed derricks. Six of eight nests reported by Idaho Power personnel and checked by Montana Fish and Game personnel were on the ground below the transmission lines. One of these contained two freshly broken golden eagle eggs. This problem may be corrected by securing traditional nests to transmission towers.

6.1.5.3. General Avoidance Reactions

Although no scientific studies are available which conclusively demonstrate that large ungulates avoid transmission lines, Klein (1971) reports that in Scandanavia reindeer (*Rangifer tarandus*) are deterred from crossing power line rights-of-way, especially for the first year or two after construction. The "hum" of the power lines is believed to disturb reindeer and result in difficulties in herding.

There is some evidence that gulls are reluctant to fly under transmission lines (Gunther 1956), and Willard and Willard (unpub.) demonstrated that waterfowl modify their flight paths to avoid transmission lines.

Hunt (1974) gathered information relating waterfowl hunting success and the presence of power lines. Although Canada geese in other areas have been observed flying and nesting near EHV power lines in Montana, Hunt stated that in his area Canada geese never flew beneath power lines in normal flight. Fog (1970), however, observed that waterfowl of several species fly near 150 KV structures without apparent fear. Hunt (1974) also documented decreased hunter success at marshes crossed by power lines and pointed out the judicial precedents for awarding damages to property owners subject to decreased hunting success following power line installation.

As a preliminary test to discover if raptors, especially the endangered peregrine falcon, were frightened by the presence of the line, a male gyrfalcon (*Falco rusticolus*) and a female peregrine falcon (both of which were trained for falconry by Peter Widener of Missoula, Montana) were released below the 500 KV Dworshak to Hot Springs line. Both birds initially flew near the conductors as if inspecting them, but both repeatedly flew beneath the lines and neither showed aversive behavior.

How wilderness species, such as the grizzly bear, react to the physical presence of a 500 KV line and the associated towers is unknown. However, increased human activity along the right-of-way and access roads, whether recreational or associated with inspection and maintenance, is likely to prevent the return of these species to the area once construction is completed. This would, in effect, reduce the extent of habitat of these wilderness species by an area much greater than that of the actual right-of-way.

6.1.5.4. Operational Impacts

A. Audible Noise

Even in fair weather corona noise is

audible, though not uncomfortable, near the 500 KV Dworshak to Hot Springs lines. Terrestrial fauna may avoid transmission corridors as a result of noise, but it is improbable that animals on the ground suffer cochlear damage.

Birds nesting on towers may suffer damage to their auditory apparatus. Guinea pigs (Cavia cobaya) suffered metabolic changes at all frequency levels when subjected to 100 db noise at various frequencies for three hours (EPA 1971a).

B. Electrochemical Oxidants

Of the chemicals produced by corona discharge of electric transmission lines, ozone, nitrogen dioxide, free radicals, and singlet oxygen are toxic to life forms (Young 1973). Hindawi (1970) reviewed and reported injury thresholds for plants at: (1) .03 ppm for four hours for ozone, and (2) 2.5 ppm for six hours for nitrogen dioxide. Mammals subjected to 0.05-0.20 ppm ozone suffered irritated mucus membranes, decreased visual acuity, sphering of red blood cells, structural changes in myocardial nuclei, and increased mortality in the newborn (Jaffe 1967). Test animals with respiratory infections suffered increased mortality from a three-hour exposure period at only .08 ppm ozone (Jaffe 1967). Humans exposed for 10 minutes to nitrogen dioxide at 5 ppm suffered increased airway resistance; after 30 minutes at 90 ppm pulmonary edema developed in 18 hours; long-term exposure at .062-.109 ppm resulted in increased incidence of acute respiratory disease (EPA 1971b).

Although pertinent data on production of the other electrochemical oxidants are largely lacking, ozone is probably the only oxidant that may approach toxic levels near transmission lines, and research indicates that even ozone concentrations are likely to be negligible. Frydman et al. (1972) gathered ozone concentration data near 765 KV energized conductors and stated that "no measurable amounts of oxidants attributable to the presence and operation of the high-voltage installations were detected." Scherer et al. (1972) and Fern and Brabets (1974) also concluded that ground concentrations of ozone due to EHV transmission lines are negligible.

In each of the references cited above, the researchers seemed most concerned with danger to terrestrial life. The closest ozone readings were taken six meters downwind from the conductors. To determine if birds nesting or perching on transmission derricks will be poisoned, critical data are needed during all weather conditions and closer to conductors. In 1974, Montana Department of Fish and Game personnel cooperated in removing and rearing two red-tailed hawks which were raised on the 500 KV Lower Monumental to John Day line in Oregon. Both birds fledged and are capable of sustained, well coordinated flight.

C. Electrocution

The electrocution of large numbers of eagles on low voltage distribution lines has been documented for over 15 years. Dickinson (1957) reported that possibly 100 eagles were electrocuted annually near Aberdeen, Idaho. In 1972 the Bureau of Sport Fisheries and Wildlife accumulated data on 155 raptor electrocutions; of these, 135 were golden eagles (USBSF&W 1973b). It was not until the 1970's that the REA and BLM began regulating power line configurations to reduce bird losses (REA 1972, and Crawford and Dunkeson 1973), and even at present regulatory measures are either voluntarily employed or are enforceable only on public lands.

Transmission lines greater than 67 KV have not been responsible for electrocutions (Boeker 1974 and Nelson 1974). The 500 KV lines considered in this report should not produce any bird electrocutions, except those due to incidental lightning strikes and flashovers.

6.1.5.5. Collisions

Nocturnal migrants are especially prone to collisions with man made obstacles. Airport ceilometers, TV towers, buildings, transmission line towers, and even the Washington Monument have resulted in bird losses (Terres 1956, and Willard and Willard unpub). Probably the greatest kill on record occurred at a ceilometer: an estimated 50,000 birds died (Johnston and Haines 1957). Most bird facilities are passerines--only occasionally do waterfowl add to the figures (Kemper 1964). Taylor and Anderson (1973) reported only four grebes and one coot among the 7,782 birds killed at a 1,484 foot TV tower. The structure height is one factor in determining the number of birds killed. Kemper reported that a 500-foot tower caused no deaths, while a nearby 1000-foot tower killed 30,000 birds in a short period.

Although transmission conductors and towers, telephone wires, and fence wires have not been responsible for losses as great as at TV towers, some bird deaths do occur. Banko (1960) reported trumpeter swans (Olor buccinator) collide with wires in foul weather. Borell (1939) recovered three sage grouse which apparently died on impact with telephone wires. Cornwell and Hochbaum (1971) reported several instances of ducks killed on impact with barbed wire fences, power and communication lines. Twenty-one of 70 mute swans (Cygnus olor) killed in a one-year interval in Great Britain, 30% of the unknown mortality, were wire strikes (Harrison 1963). Other wire collision records include a male Allen's hummingbird (Selasphorus sasin) (Hendrickson 1949), approximately 1000 night migrants at Oak Ridge, Tennessee (Johnston and Haines 1957), fulvous tree ducks (Dendrocygna bicolor) in Louisiana (McCartney 1963), ring-necked ducks (Aythya collaris) (Mendall 1958), five lesser sandhill cranes (Grus canadensis) (Walkinshaw 1956), two ring-necked pheasants (unpub. data), and Japanese sacred cranes (Archibald 1974).

Stout (1967) accumulated records of non-hunting mortality of waterfowl. Of over 3000 birds recovered dead from many causes, 1507 were killed on wire strikes. He found that puddle ducks were most prone to wire strikes; males were more prone than females, and most strikes occurred during migration. This study and the others cited above suggest that water fowl migration routes, and key concentration areas should be avoided when siting transmission lines. The tendency of waterfowl to fly near the ground when approaching stopover areas and when crossing ridges and mountain passes (Eng 1974) also suggest that transmission lines should avoid these topographic features where they coincide with migration routes.

6.1.5.6. Other Impacts

If the public has access to maintenance roads, hunting pressure on game species will increase in some areas, and raptors and other birds which perch and nest on the towers will receive increased pressure from indiscriminate shooting. Shooting of perched raptors from roadways near power lines can reach significant proportions. In a western Utah study area, Ellis et al. (1969) recovered 30 dead raptors in one day along a 12-mile segment of distribution lines. None of these birds showed electrocution burns. Most (although some were dead over one year) exhibited bullet and shot holes. Fourteen of the birds were golden eagles. Extensive surveys of other likely kill sites revealed additional shot birds, but not as extensively as along the initial survey road.

Where increased hunter pressure is undesirable, public access should be denied, and in areas where raptors are likely to perch and nest, it is to the birds' advantage if public roads are at least one half mile distant.

The magnetic fields around the conductors may yeild another hazard to bird life. Keeton (1969), expanding on the work of others, found that pigeons (Columba liva), unfamiliar with the release site, were able to efficiently navigate homeward when released under overcast skies. One likely navigational cue used by birds under overcast conditions is the earth's magnetic fields. If some wildlife species do not use magnetic fields to orient and navigate, what will be the effect on the young of these species that are reared in the magnetic fields near high voltage transmission lines?

6.1.5.7. Negative Effects of Wildlife on Transmission Lines

In two years, BPA suffered 32 outages as a result of unexplained flashovers (West et al. 1971). Subsequent laboratory studies implicated raptorial birds as the most probable source of this problem. In theory, a bird, perched on or flying near the tower, defecates near the insulator string, and the stream of excreta bridges the gap between a conductor and the tower. Ausland (1974) stated that repeated defecations on insulator strings below a raptor nest are also responsible for flashovers.

One possible solution is to make the towers unsuitable for perches and to destroy the nests. A more environmentally sound solution is to make the towers unsuitable for perching and nesting only immediately near the insulator strings, thereby allowing the birds to nest elsewhere on the structure where they will cause no damage. Hoaglin (Unpub.) of BPA successfully experimented with moving nests within a tower to positions where they caused no damage.

6.1.6. Impacts on Meteorology

6.1.6.1. Construction

A. Climatology

No impact of construction of the transmission line on macro or meso scale climate is anticipated. Construction would affect microclimate insofar as the existing vegetative cover would be disturbed in access road and right-of-way preparation. The clearing of vegetation would result in higher wind speeds near the ground and a corresponding decrease in ground level humidity in the cleared area. The local radiation balance would also be altered due to increased insolation. Restoration of the previously existing vegetation after the construction period would reverse these impacts, but such restoration may not always be possible because of right-of-way maintenance considerations.

B. Air Quality

Impacts on existing air quality would include an increase in dust levels and vehicular emissions, and possibly in emissions from open burning (and herbicide spraying). Dust produced by vehicular traffic and construction work will cause some increase in particulate pollution. Efforts should be made to minimize dust by sprinkling roads and construction areas with water and retaining the vegetative ground cover whenever possible. Gaseous and particulate emissions would cause a temporary impact on air quality, but no long-term detrimental effects should result. Open burning of cleared vegetation or other wastes is also a potential source of particulate and gaseous pollutants and should be avoided. Any open burning will be subject to existing state and federal regulations.

6.1.6.2. Operation

A. Climatology

No impact on climate due to transmission line operation is anticipated.

B. Air Quality

Because the production of oxidants such as ozone and nitrogen oxide occurs during corona discharge, the transmission lines would have some impact on air quality. Only limited information is currently available on which to base a prediction of the levels of oxidant production, and hence the magnitude of impact, of 500 KV transmission lines. Available information tends to indicate that the oxidant production rate would be so small as to make any air quality impact negligible.

Scherer, Ware, and Shih (1972) reported on three laboratory investigations of oxidant production rates. These experimental rates were combined with available corona loss data for the West Virginia Apple Grove Project 765 KV test lines. Diffusion calculations using a mathematical model (Gaussian line and point source models) were made to estimate the maximum oxidant concentrations which might occur near 765 KV lines. /1 The maximum ground level concentration predicted, assuming no oxidant decay, was 0.02

ppm./2 On the basis of the predicted concentrations, Scherer et al. concluded, "Analytical studies based upon conservative assumptions and calculations indicate that the probability of measuring ground level incremental concentrations is essentially zero" (p. 8).

Oxidant measurements were made by Frydman, Levy, and Miller (1972) intermittently over a one-year period in the vicinity of energized 765 KV lines, under various terrain and weather conditions. Frydman et al. concluded, "under conditions of these tests, no measurable amounts of oxidants attributable to the presence and operation of the high-voltage installations were detected" (p. 1).

Roach, Chartier, and Dietrich (1973) made wind tunnel measurements of production rates of ozone and oxides of nitrogen for single and bundle conductors of transmission lines in wet and dry corona. These production rates were combined with Apple Grove 765 KV test line corona loss data to give ozone and nitrogen oxide production rates appropriate for a diffusion model analysis. Using the Gaussian line and point models, Roach et al. made predictions of both ground level and conductor height ozone concentrations in both fair and foul weather for winds parallel and perpendicular to the transmission line. At a distance of about 50 feet downwind of the line, all predicted concentrations reported were less than about .01 ppm. /3 No attempt was made to include atmospheric decay of ozone. Nitrogen oxide concentrations were reported to be an order of magnitude less than the ozone values. Roach et al. concluded that the predicted concentrations were too low to be deleterious to the environment as they were less than the values specified as harmful to plants and animals in the Air Quality Criteria published by HEW and EPA.

In a study for EPA, Witmore and Durfee (1973) made laboratory measurements of ozone production rates from a sub-scale simulation of a high-voltage transmission line. The rates measured were consistent with those determined by Roach et al. and Scherer et al. Using their own measurements of average ozone production rates, estimated average corona losses, three different ozone half-lives, and a simple box dispersion model, Witmore and Durfee calculated ambient ozone concentrations for three areas containing high concentrations of transmission lines. The total number of miles of three-phase transmission lines operating at 115 KV and higher was used as the emission source in each area. The box was assumed to be closed so no ventilation was possible. Also, ozone was assumed to mix uniformly throughout the box./4 The steady state ozone concentration in the region with the highest predicted concentrations were:

O_3 Half-Life (hr.)	Concentration ppb by volume
1	6.8×10^{-3}
10	6.8×10^{-2}
100	6.8×10^{-1}

Whitmore and Durfee concluded:/5

> Ozone from transmission lines appears to contribute only minimally to local ozone levels in areas where concentrations of

> transmission and distribution lines exist. However, this result is based on extremely rough estimates of ozone lifetimes in free air (p. 79).

Fern and Brabets (1974) reported on a continous field investigation of ozone concentration in the vicinity of high-voltage transmission lines. The study area was located near Chicago, Illinois. Measurements of ozone concentrations were made at four sites: 1) a site "...25 feet below the center of a 345 KV line with a heavy concentration of six other 345 KV lines within 200 yards" (p. 2); 2) a "typical suburban residential area" site 2.1 miles from the 345 KV site to obtain ambient ozone levels; 3) a site located on the edge of a right-of-way 100 feet from the centerline of a 765 KV lines; and 4) another ambient air site located 1.2 miles from the 765 KV site. The first two sites were operated simultaneously from April 1971 to April 1972, the third from July 1971 to October 1972, and the fourth from May 1972 to October 1972. The authors concluded "...high-voltage transmission lines have no measureable effect on the ozone present in the atmosphere at ground level adjacent to the lines" (p. 1).

One measurement of ozone concentrations possibly attributable to transmission lines that is significantly higher than those predicted and measured in the previous studies has been reported by Oak Ridge National Laboratory (Oak Ridge National Laboratory 1972). On April 6, 1972, at 9:30 and 9:40 a.m., ozone concentrations of 0.21 and 0.23 ppm were measured at the "edge of two 500 KV transmission line right-of-ways" (p. 36) located on the Oak Ridge Atomic Energy Commission Reservation. Background ozone concentration at a location designated "ORNL" measured at 9:00 a.m. on the same day was 0.02 ppm. According to the Oak Ridge report, "...subsequent analysis at the same location yielded ozone concentrations ranging from .02 to .03 ppm, suggesting that the extremely high concentrations reported on April 6 may have been due to a moderate temperature inversion" (p. 37).

In a subsequent report entitled "Environmental Impacts Associated with Electric Transmission Lines" by Kitchings et al. (1974), also an Oak Ridge group, no mention was made of the April 6, 1972, high values. Kitchings et al. stated, "Preliminary studies conducted at Oak Ridge National Laboratory indicate that concentration directly beneath the transmission lines may approach 1-2 ppb" (p. 62). Evidently, the singular high measurements did not represent a significant trend.

In summary, the available laboratory and field data for high-voltage transmission lines operating at voltages up to 765 KV appear to indicate that no significant impacts on air quality will occur due to oxidant production in corona discharge with respect to existing air standards.

In their 1973 paper, Roach et al. stated, "Present experimental data is insufficient to establish reliable analytical predictions of the rates of corona produced effluents for transmission line conductors" (p. 653). Work published since the Roach et al. statement has not substantially altered this situation. For this reason, and because studies to date do not indicate a significant impact of transmission lines on air quality, no attempt will be made to select transmission line corridors on the basis of ozone production rates.

6.2. Cultural Environment

6.2.1. Impacts on Existing Land Use

The severity of potential transmission line impacts on land use is cumulatively determined by the types of land uses involved, the tower locations, the construction technique used, the existing vegetative ground cover, the miles of access road generated, the corridor's aesthetic impact, and any resultant impacts on land uses of adjoining areas. The proposed line would be about 430 miles long and would require a 300-foot corridor, thereby directly affecting 15,636 acres and indirectly affecting an unknown number of adjacent acres. There are two general types of impacts which would result from the proposed line: physical and attitudinal. The former indicates interference with agricultural practice, acres of potential erosion, etc.; the latter represents the impact of transmission lines on public opinion, and resultant sociologic behavior. Both types of impact are significant, but physical impacts are more easily quantifiable.

6.2.1.1. Agricultural Land Uses

Impacts of transmission lines on agricultural land uses are determined by the specific locations of tower bases and guying cables, possible electrostatic and electromagnetic influences, access road locations, legal restrictions on land use beneath the lines, and construction activity. The location of the corridor on agricultural land may necessitate a change in agricultural practices currently in use on that land, such as aerial spraying techniques, contour plowing, and mechanical irrigation as an adjustment to tower height and foundations. Construction activity during the planting, growing, and harvesting seasons can severely limit the amount of productive land in the right-of-way. Range livestock feeding patterns will also be disrupted when animals avoid construction areas (Hope 1974), which, depending on the location and time of year, can affect pasture and range rotation schedules.

The long-term implications of short-term nuisances such as irrigation system interference can make marginal agricultural lands economically unfeasible for continued production. The number of tons or bushels of specific products that would be lost in each county is tabulated in Table 14 of Appendix M. The figures represent the production from a piece of land 300' wide and 5,280' long, the amount of land which would be removed from production by a corridor one mile long. Actual predictions of crop loss for each county cannot be made at this time, because no corridor has been approved. Many problem areas and land losses can be avoided by consultations with current land users in order to coordinate construction phases with agricultural phases.

6.2.1.2. Urban Land Uses

Impacts of transmission lines on urban land uses include possible interference to communication systems, audible noise, site specific tower location interferences, and aesthetic influences; also, like any other linear land use pattern the line will define or divide urban spaces with possible potential sociologic implications. Public reaction to a transmission line corridor in Billings in 1974 demonstrated the social concern about corridor location in an urbanizing section of the city; the negative reaction is indicative of the undesirability of the line in proximity to residential areas. Interference with television and radio reception on certain lots in Red Lodge, Montana, caused a devaluation of those lots by 10% (Snyder 1974). If these indications imply factors affecting urban growth, then distance from and views of the power line would affect property values and the demand for those properties, thereby introducing a new determinant for urban land use.

The addition of power line corridors to urban areas has the potential for positive as well as negative effects. The corridor as a linear element can be incorporated into future transportation circulation systems or linear park schemes; heat from line loss may one day be harnessed by technology for useful purposes. If used with growth plan objectives of local planning authorities, corridors can direct urban sprawl to community advantage, but prior consultation and coordination is necessary.

Urban areas have traditionally been the most sensitive to the aesthetics of power lines due to the large number of people affected. Larger population centers require the proximity of transmission lines to supply the collective demand; however, urban land use, represented by a vocal majority of the population, puts undue stress on surrounding land uses, represented by a smaller, rural population, for accommodating the corridor.

6.2.1.3. Recreation

One present land use that is also critical to the future is recreation.

> The United States is one of the nations most blessed in natural resources. It is growing rapidly. The population and its leisure time are also increasing. Recreational activities are multiplying. Many freedoms, great mobility, and much individual independence is enjoyed. Therefore, it will be incumbent on all of its people to protect, control, and replenish as much as possible of the natural resources. (Rotunno 1966)

In 1973, the Task Force on Land Use and Urban Growth (created by the President's Citizens Advisory Committee on Environmental Quality) reported: "the categories of land which...ought to be kept natural, or at least free of development include...areas required for future public recreation". (Reilly 1973)

The rationale substantiating the growing concern about recreational opportunities derives from the relationship between basic human needs, recreation, and the pressures of industrial society.

> Beyond the essential physical needs to eat, breathe, sleep, and excrete, there are several less obvious, but deep seated, biological needs that man shares with other animals. These needs for personal space, for territorial elbow room, for contact with other animals, and with plants, for social interaction within small clans, and family groups, and for diversity in surroundings all derive from our prehuman origins. Man's needs likewise are conditioned by the cultural background of each population. (Stearns 1972)

The needs of the individuals "for contact with other animals, and with plants,...and for diversity in surroundings are collectively represented within the scope of recreation; this perspective of recreation also recognizes that leisure time is not strictly a frivolous diversion.

> Recreation is made necessary by the stress to which modern man is subjected in our industrial society...today recreation is no longer conceivable as simple relaxation or distraction. ...In an industrial society, recreation ranks equally with working, having a place to live, communicating, educating oneself, and being part of the community. Today the entire human being, body, soul, and mind needs recreation. (Rohlfs 1966)

In 1970 there were about 480 million visits to state and national parks in the United States, which, when compared to about 265 million visits in 1960, is a 55% increase in ten years (Reilly 1973). There were 5,132,400 visitors in Montana's National Forests alone in 1973, representing 9,932,400 visitor days of recreation time (one person in a forest for twelve hours equals one visitor day). The recreational demand on parks and forests in Montana is generated by a national user group as well as by Montana residents. This demand will increase because of population expansion, with the majority projected to live in urban areas (Reilly 1973) with an increase in individual leisure time, mobility, and income. The land area of Montana's designated state and national parks, forests, and other recreational areas is finite. Because there is a growing need for a variety of recreational experiences, those lands presently alloted to public use become a major constraint on corridor location, if they are to preserve their natural character, and therefore, their attraction.

The Specially Managed Areas Map identifies public land categories of existing recreational attractions, and includes natural, wilderness, and primitive areas of varying size and scenic waterways. The Recreation and Cultural Features Map locates specific outdoor recreation sites administered by the public and private sectors (the types of sites inventoried are listed in Section 5.2.1.). Transmission lines passing through or over these areas and activity nodes would create direct environmental effects as described in other sections of this statement. An intangible impact would also result from the physical and aesthetic impacts, thus affecting an individual's perception and enjoyment of the transgressed area. These impacts are more difficult to quantify than physical impacts, since they tend to be subjective determinations of the importance of scenic beauty or the pristine nature of an area to particular recreational pursuits and to the recreationist. However, it can generally be said that recreationists who leave urban areas for outdoor activities are motivated to do so by an appreciation of and a need to be in a natural landscape. Transmission lines can only detract from natural aesthetic beauty, and the recreational experience is diminished proportionally. Therefore, the capability of the land to satisfy man's need for outdoor recreation is reduced.

6.2.1.4. Archaeologic and Historic Sites

Included among specific outdoor recreation sites are three unique categories: archaeological sites, historical districts, and historical sites (see Recreation and Cultural Features Map). These sites are irreplaceable historical documentation of man's developing technology and habitation patterns, and they have maximum value when artifacts are undisturbed and the visual setting is most near its original state. Due to the critical importance of specific locations of artifacts on an archaeologic site or historic site, disruption of these areas has the potential for more significant impacts that would render them valueless to future investigations. If the lines are approved, known sites should be avoided, especially those listed in The National Register of Historic Places (U.S. Department of Interior 1973). Also, a procedure should be established to insure professional surveying of any archaeologic evidence discovered.

6.2.1.5. Aesthetic Impacts

The power of the landscape to stimulate an individual's senses and evoke a feeling of beauty and pleasure is in a direct relationship with the ingredients in that landscape. Variables that affect perception are distance to perceived objects, weather conditions, terrain masking of those objects, and the context in which the objects appear—i.e., constructing a transmission line in an industrial area lowers the aesthetic quality of its surroundings less than constructing a transmission line in rolling country. These impacts are not quantifiable, and are therefore impossible to measure and difficult to discuss or predict. Quiet disappointment and eventual frustration will not appear on any balance sheet; they are attitudinal rather than physical impacts. The reduction in beauty of a landscape caused by the presence of a transmission line can be observed, but the impact of that reduction of beauty can only be felt. For some (In a public opinion survey discussed in Section 11.2.2.2. of Volume 3b of this impact statement, 35.2% of respondents living in the study area considered the "beauty of the area" an important reason for living there.), a reduction in the beauty of a significant landscape would constitute a significant reduction in the quality of life. The length of the proposed corridor, 430 miles, is not a true quantitative indicator of aesthetic impact, but it does serve as a starting point from which to estimate the scope of the landscapes that would be changed. Transmission lines are not an improvement on most landscapes, but if the allignment and corridor design are aesthetically oriented rather than strictly economically oriented, the aesthetic impacts are lessened. There are few land areas between Colstrip and Hot Springs that would harmonize with the aesthetics of the lines, and therefore the discord of this element would be perceived in many landscapes by many observers for as long as the lines exist.

The number of people who view a transmission line is also not a true quantitative indicator of aesthetic impact. Section 70-802 of the Montana Utility Siting Act addresses its purpose to future generations. Therefore, an estimate of visual impact of transmission lines should include a concern for population growth and future visual impact. The number of people viewing the line and the relative aesthetic impact of the line on its surroundings might change considerably during the lifetime of the line. Another reason that the current-number-of-viewers theory is invalid is based on the concept of expectancy. More people would see the line if it were routed near an urban area, but the viewers' expectation of scenic beauty would not be as high in such an area. Visitors at a state park would probably have expectations of scenic beauty; under these circumstances, the impact of encountering a major transmission line would be magnified. The same is true of most recreation areas, including historic sites, national forests, and urban parks. The number of users of these areas does not accurately reflect the potential aesthetic impact of a transmission line on those areas.

6.2.2. Proposed and Potential Land Use

Future land use falls within two categories, proposed and potential, with the former indicating a specific land use designation and therefore a strong probability of implementation; the latter is more susceptible to change. If the proposed lines are constructed, they will become another determinant for the types of land use within the corridor and adjacent to the corridor. Other criteria that also affect land use are public need, economic feasibility, land compatibility, and technology; a change in any one of these determinants can change the potential land uses in any given area. Since power lines are not aesthetically attractive by current societal values, it can be assumed that potential residential, commercial, and recreational land uses would be located to avoid the lines when possible. Existing and potential agricultural land uses can be directly influenced by tower locations, right-of-way land use restrictions, and possible electrostatic or electromagnetic affects. Any degradation of natural or primitive areas could preclude their inclusion in a more restricted, and thus more protected, category designation.

Proposed and potential land uses would be affected by transmission lines as present land uses are, but they have one more restriction--the constraint of the presence of the line itself. If this is a critical factor, particular land uses will not occur. If it is not a critical factor, then the conversion from proposed to actual land use will only be affected by normal restrictions.

6.2.3. Impacts on Population and Social Factors

The Westinghouse report (1973) projected that 300 construction personnel will be needed to build transmission line segments of approximately 110 miles in length. Six months of construction time was projected for each line segment. Montana Power Company has recently revised these estimates. They suggest that contractors would be "lucky" to find 150 qualified personnel (Ross 1974) and that actual construction time will more closely approximate 15-18 months than six months (MPC 1974).

Construction schedules for the 500 KV lines have not been prepared, although the Westinghouse report (1973, Section 3.7.1.1.) suggests that line construction will require five years to complete. Construction will proceed in scheduled phases for surveying and staking, clearing right-of-way, road construction, tower construction and erection, stringing conductors, and clean-up and restoration. Work crews ranging from three or four persons up to 25 or 30 persons, scattered along the length of a line segment, will perform these tasks (see Section 4.3.). For any given line segment, construction crews will be at work for 6 to 18 months.

6.2.3.1. Population

Population influx is related, primarily, to crew size and to the extent to which construction personnel are in-migrants. Assuming that the entire construction work force is composed of in-migrants and that 50% of the workers are accompanied by 2.5 dependents,/7 the probable range of population increase would be from 225 to 675 persons per line segment. See Table 6-1.

Table 6-1

ESTIMATED POPULATION INFLUX PER 110 MILE TRANSMISSION LINE SEGMENT 1.

Crew Size	Population Increase
100 Personnel	225 Persons
150 "	338 "
200 "	450 "
250 "	563 "
300 "	675 "

1. Assumptions:

1) All construction personnel are in-migrants.

2) 50% of the construction workers will be accompanied by 2.5 dependents.

The usual practice in transmission line construction is to hire local residents to provide much of the construction labor, particularly for such tasks as right-of-way clearance. Specialized skills necessary for erecting towers and stringing conductors, in most cases, requires imported manpower./8 Assuming that 50% of the construction crews can be hired locally and that the remaining 50%, composed of imported manpower, is accompanied by 2.5 dependents, the range of estimated population growth is from 113 to 338 persons per line segment (see Table 6-2).

Table 6-2

ESTIMATED POPULATION INFLUX PER 110 MILE TRANSMISSION LINE SEGMENT [1].

Crew Size	Population Increase
100 Personnel	113 Persons
150 "	169 "
200 "	225 "
250 "	281 "
300 "	338 "

1. Assumptions:

    1) 50% of the construction crew is hired locally.

    2) 50% of the in-migrants are accompanied by 2.5 dependents.

Locally hired personnel are not counted in the latter estimates since they are already part of the area base population and do not add to population growth. Depending on crew size, the population growth estimates from 113-675 persons may be viewed as a range of probable population increase along any given segment of the transmission line. It is important to remember, however, that construction delays, changing characteristics of the labor force, or other factors may radically alter these population estimates. While it is improbable that the construction of the transmission lines will result in a population growth of fewer than 113 persons per line segment, increases in overall crew size, the need to import larger numbers of men to specific areas, or the presence of more dependents may shift the estimated population increase above the indicated upper limit of 675 persons.

The projections above do not include an estimate of population growth that may stem from secondary employment opportunities. While a population increase due to construction activities may stimulate an increase in demand for additional services, it is expected that secondary employment will be minimal and that the local labor force would be able to accommodate such an employment demand should one arise. This assumption is made because the population increase associated with transmission line construction is transient and relatively small.

The population distribution is as important as the absolute numbers of people. While work crews may be scattered along the length of the transmission corridor, construction personnel would probably locate their places of residence at a few communities along the line segment. Terminal points along each line segment, such as Colstrip and Broadview, would experience larger population increases than most intermediate points since terminal points will experience substation construction and may act as equipment staging areas. The specified scope of population increase in any given community is not calculable and would depend upon variables already mentioned as well as such variables as the number of men hired locally, local housing opportunities, available social and recreational services, and proximity to the construction site.

6.2.3.2. Impact on Social Organization and Life Styles

The social impact which would be created by construction of the 500 KV lines is expected to be minimal. The presence of migrant construction workers and their families would not appreciably alter the existing social organization of the communities involved. Unlike the Colstrip area where large numbers of newcomers have inundated the existing population and its social order, the expected population increase associated with transmission line construction is relatively small, transient, and would probably be diffused along the length of the line segment. Local business communities can expect some increase in demand for goods and services. Owners of residential rental property and trailer parks can expect an increased demand for housing. Some social disorganization, particularly in the form of rowdy behavior and fighting, may also be expected, especially within local taverns where construction personnel may congregate. Trespassing on private property may also be expected as construction crews move equipment to job sites, travel to work, or seek outdoor recreational activities such as hunting, fishing, picnicing, and snowmobiling.

The largest group of negative social impacts associated with construction activities are property damage and inconveniences to landowners whose property is crossed by the transmission line right-of-way. Interviews with property owners in the Thompson Falls area whose land is currently crossed by transmission lines indicated the following negative impacts:

1) Property damage to crops, agricultural land, fences, and gates by construction crews straying off the right-of-way or access roads with private vehicles and construction equipment.

2) Gates left open with the resultant effect of agricultural animals (mainly cattle and horses) getting out of the fenced enclosure, and requiring extra time spent in locating and herding them. These livestock constitute a hazard to operators of motor vehicles and represent a potential property loss to their owners should they be killed or injured in some manner. They could also be the cause of crop damage should they wander into neighboring fields.

3) Improper clean-up and restoration following line construction. Interviewees indicated that piles of slash are often left in the right-of-way, and debris such as paper and glass and metal containers are strewn by construction workers and constitute a threat to livestock. Also, soil disturbed by construction activities is not always properly restored and reseeded.

Long-range impacts caused by transmission line construction were indicated as follows:

1) Tower structures take cropland out of production. This problem is exacerbated when more than one line is located on the right-of-way. When tower structures

are staggered, as they are in the Thompson Falls area because the tower spans of the different lines vary in length, the movement of agricultural equipment becomes difficult, if not impossible. One interviewee suggested that the presence of the many tower structures made the right-of-way unsuitable for any agricultural use other than grazing.

2) Maintenance personnel create nuisances and inconveniences similar to those caused by construction crews by moving equipment through cropland, damaging fences and gates, leaving gates open, and failing to remove debris.

3) Corona effects and audible noise were cited as nuisance impacts. A number of respondents indicated that the quality of TV and radio reception declined with the operation of transmission lines, particularly with increasing proximity to the facility.

4) An aesthetic impact was indicated in that tower facilities reduced the scenic value of the area and that the clearing of the right-of-way left a scar on the landscape.

A. State-Wide Public Opinion

The following discussion presents results of a public opinion survey concerning energy-related issues conducted by the Energy Planning Division during the week of August 26, 1974. Only the responses to questions concerning transmission facilities are presented below. A detailed description of the survey, the methods of analysis employed, and a discussion of responses concerning power plant construction, industrial development, and strip mining are presented in Volume 3, Section 11.2.2.2. of this impact statement. Appendix H of Volume 3b includes a copy of the questionnaire which was mailed to 2,200 Montana residents in conducting the survey.

Generally, attitudes expressed toward electric transmission facilities were not as clear-cut as are the opinions expressed about strip mining (see Tables 6-3 and 6-4). The "neutral" category was frequently used by respondents.

An item asking if the respondent favored the construction of high voltage transmission lines in Montana met with 40.3% disapproval, 36.3% approval and 22.2% neutral. An examination of this item by income level (Table 6-5) and occupational category (Table 6-6) indicates that high-income groups and those with professional and technical occupations are slightly more negative toward transmission facilities than are other categories of respondents.

A clear majority of respondents (59.6%) indicated that they preferred to live in an area without the presence of high voltage transmission facilities. Examination of this item by income level (Table 6-7) and occupational category (Table 6-8) did not reveal a clear differentiation between respondent categories. Again, the neutral category was frequently chosen (24.3%).

An item asking if the respondent had any objection to the location of a high voltage

TABLE 6-3

Montana Energy Survey

Transmission Lines

I favor the construction of high voltage electric transmission lines within Montana.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
7.3%	29.0%	22.2%	18.1%	22.2%

No Response 1.2% Total N = 775

I would prefer to live in an area without the presence of high voltage electric transmission lines.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
32.0%	27.6%	24.3%	11.7%	3.4%

No Response 1.0% Total N = 777

I would have no objection to the presence of a high voltage electric transmission line on my property.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1.9%	17.0%	16.3%	25.3%	37.4%

No Response 2.1% Total N = 423

Provided high voltage electric transmission lines are not located on my property, I have no objection to having them built elsewhere.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
0.9%	12.3%	26.5%	35.9%	22.0%

No Response 2.4% Total N = 423

TABLE 6-4

Montana Energy Survey

Transmission Line

High voltage electric transmission lines should be constructed in areas where power lines currently exist.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
11.1%	48.5%	22.5%	12.3%	4.0%

No Response 1.7% Total N = 423

High voltage electric transmission lines should be built in relatively uninhabited areas of the state.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
9.2%	35.9%	19.4%	23.2%	10.4%

No Response 1.9% Total N = 423

High voltage electric transmission lines should only be constructed if they are designed to specifically serve Montana residents.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
14.4%	35.2%	17.3%	26.7%	4.7%

No Response 1.7% Total N = 423

Power companies should pay an annual fee to property owners whose lands are crossed by electric transmission lines.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
27.7%	44.9%	17.3%	7.6%	1.7%

No Response 0.9% Total N = 423

Question: I favor the construction of high voltage electric transmission lines within Montana.

TABLE 6-5

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	0.3 (1.1)	0.0 (0.0)	0.4 (0.7)	0.6 (1.1)	1.9 (1.8)	3.1 (1.2)	0.9 (0.3)	0.1	7.3 (6.2)
Agree	0.6 (2.6)	1.2 (2.7)	2.2 (3.5)	3.2 (5.7)	8.5 (8.0)	8.0 (3.3)	4.4 (1.2)	0.9	29.0 (27.0)
Neutral	0.5 (2.0)	1.9 (4.5)	3.0 (4.8)	3.0 (5.3)	5.3 (5.0)	5.3 (2.2)	1.8 (0.5)	1.4	22.2 (24.3)
Disagree	0.5 (2.0)	0.8 (1.8)	2.1 (3.4)	1.9 (3.4)	5.2 (4.9)	5.0 (2.0)	1.4 (0.4)	1.2	18.1 (17.9)
Strongly Disagree	0.6 (2.6)	1.2 (2.7)	1.3 (2.0)	4.5 (8.0)	5.4 (5.0)	5.2 (2.0)	2.7 (0.7)	1.3	22.2 (23.0)
No Response	0.0 (0.0)	0.0 (0.0)	0.4 (0.7)	0.4 (0.7)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.3	1.2 (1.4)
Total	2.5 (10.3)	5.1 (11.7)	9.4 (15.1)	13.6 (24.2)	26.3 (24.7)	26.7 (10.7)	11.2 (3.1)	5.2	100.0 (98.8)

N = 775
Adjusted N = 735

Top Figure A Raw Percentage
Figure in Parentheses An Adjusted Percentage

Question: I favor the construction of high voltage electric transmission lines within Montana

TABLE 6-6

MONTANA ENERGY SURVEY

Occupational Category	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Response	Total
Professional, Technical and Kindred Workers	1.6	8.7	6.8	6.5	10.2	0.1	33.9
Business, Managers, and Administrators	1.2	3.4	1.9	1.3	1.4	0.1	9.3
Sales and Clerical Workers	0.4	1.9	2.3	1.8	1.4	0.1	8.0
Craftsmen, Foremen and Kindred Workers	1.0	1.8	1.2	0.6	0.6	0.0	5.3
Operatives and Service Workers	1.6	5.4	3.7	3.0	2.7	0.1	16.5
Homemakers	0.1	2.2	1.0	1.4	1.0	0.0	5.8
Agriculture, Farm Owners, Managers, and Workers	0.8	1.9	1.7	1.4	1.4	0.0	7.2
Retired	0.4	1.2	1.2	0.5	1.0	0.3	4.5
Unemployed, Students, and Occupational not Specified	0.3	2.6	2.3	1.6	2.3	0.4	9.4
Total	7.4	29.1	22.1	18.1	22.0	1.1	100.0

N= 774

Figures are Raw Percentages

Question: I would prefer to live in an area without the presence of high voltage electric transmission lines.

TABLE 6-7

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	1.3 (5.3)	2.1 (4.7)	2.7 (4.3)	5.5 (9.8)	6.8 (6.4)	8.1 (3.3)	3.5 (1.2)	2.1	32.1 (35.0)
Agree	0.8 (3.1)	1.0 (2.3)	2.3 (3.8)	2.7 (4.7)	8.6 (8.1)	7.6 (3.0)	3.2 (0.8)	1.3	27.5 (25.8)
Neutral	0.5 (2.0)	1.4 (3.3)	3.1 (5.0)	4.4 (7.7)	6.7 (6.4)	4.9 (2.0)	2.3 (0.5)	1.0	24.3 (26.9)
Disagree	0.0 (0.0)	0.4 (0.9)	1.0 (1.6)	0.9 (1.6)	3.0 (2.8)	4.4 (1.8)	1.8 (0.1)	0.3	11.8 (8.8)
Strongly Disagree	0.0 (0.0)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.8 (0.7)	1.4 (0.5)	0.5 (0.1)	0.3	3.3 (2.2)
No Response	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.3)	0.4 (0.4)	0.3 (0.1)	0.0 (0.0)	0.3	1.1 (0.8)
Total	2.6 (10.4)	5.0 (11.5)	9.2 (15.0)	13.7 (24.4)	26.3 (24.8)	26.7 (10.7)	11.3 (2.7)	5.3	100.0 (95.5) 9

N = 777
Adjusted N = 737

Top Figure a Raw Percentage
Figure in Parentheses an Adjusted Percentage

Question: I would prefer to live in an area without the presence of high voltage electric transmission lines.

TABLE 6-8

MONTANA ENERGY SURVEY

Occupational Category	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Response	Total
Professional, Technical and Kindred Workers	12.7	10.2	6.6	3.4	0.8	0.3	34.0
Business, Managers, and Administrators	3.1	2.4	2.4	1.2	0.3	0.0	9.4
Sales and Clerical Workers	2.7	2.3	2.2	0.6	0.1	0.0	7.9
Craftsmen, Foremen and Kindred Workers	0.9	1.3	1.8	0.8	0.6	0.0	5.4
Operatives and Service Workers	3.7	4.4	4.9	3.0	0.6	0.0	16.6
Homemakers	1.8	1.8	1.5	0.4	0.1	0.1	5.7
Agriculture, Farm Owners, Managers, and Workers	2.4	1.7	1.8	1.0	0.1	0.1	7.1
Retired	1.4	1.0	1.3	0.4	0.3	0.1	4.5
Unemployed, Students, and Occupational not Specified	3.2	2.3	1.8	1.0	0.6	0.4	9.3
Total	32.0	27.4	24.3	11.8	3.5	1.0	100.0

N= 776

Figures are Raw Percentages

transmission line on his personal property indicated a strong current of disapproval (62.7%). Again, in relation to income level (Table 6-9), no clear pattern differentiates the various income categories. A slightly smaller percentage of respondents (57.9%) indicated disapproval of building transmission lines even if they were not located on their personal property. Middle income groups were slightly more negative on this item than were others (Table 6-10).

Using existing transmission corridors for future transmission line construction was strongly supported by respondents (59.6%). However, the idea of building transmission lines in relatively uninhabited areas of the state was only moderately supported (45.1%). Almost 34% of the respondents disapproved of the idea; 19.4% took a neutral position. Income level did not appear significant in relation to the item concerned with using existing corridors (Table 6-11), though respondents in the higher income brackets were slightly more negative to building transmission facilities in relatively uninhabited areas of the state (Table 6-12).

Respondents generally approved of the idea of building transmission lines for the specific use of Montana citizens (49.6%). However, respondents from the higher income levels tended to disagree with this concept (Table 6-13).

An item suggesting that power companies pay an annual fee to landowners whose property is crossed by transmission facilities was met with strong approval (72.6%). Income level did not appear a significant differentiating feature (Table 6-14).

In summary, it appears that respondents are generally opposed to the construction of high voltage transmission lines. They prefer to live in areas without the presence of the lines and do not want such facilities on their personal property. Existing corridors are the preferred location for future line construction, especially if the corridor is in a relatively uninhabited area. However, the idea of running transmission corridors through relatively uninhabited territory is met with only modest approval. Finally, there is strong sentiment for the idea that power companies pay annual fees for transmission line right-of-way.

6.2.3.3. Impacts on Social Services

The impact of the transmission facility on social services varies depending on population increase and distribution, and the existing capacity of social services. The small and transient nature of the construction crews and their expected dispersal along the transmission corridor segments suggests that existing social service delivery systems should be adequate to deal with the expected population influx. The work load of certain social services such as police protection may be expected to increase to some degree, but unless the service delivery systems of a community or county are already deficient, the additional population should not require added services or service personnel. Also, the transient nature of the population influx discourages improvement of social service delivery systems, as do the budgetary constraints of social service agencies.

Question: I would have no objection to the presence of a high voltage electric transmission line on my property.

TABLE 6-9

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	0.0 (0.0)	0.0 (0.0)	0.7 (1.0)	0.0 (0.0)	0.7 (0.5)	0.0 (0.0)	0.0 (0.0)	0.5	1.9 (1.5)
Agree	0.2 (1.0)	0.5 (1.2)	1.2 (1.7)	1.7 (2.7)	5.7 (5.0)	5.2 (2.2)	2.6 (0.7)	0.0	17.0 (14.5)
Neutral	0.2 (1.0)	0.7 (1.7)	1.4 (2.2)	3.1 (5.2)	4.5 (4.0)	4.0 (1.7)	1.7 (0.5)	0.7	16.3 (16.3)
Disagree	0.9 (4.2)	1.2 (2.7)	2.1 (3.2)	3.5 (6.2)	7.8 (6.7)	5.2 (2.2)	2.6 (0.7)	1.9	25.3 (25.9)
Strongly Disagree	0.9 (4.2)	2.4 (5.7)	4.5 (7.0)	5.7 (9.7)	9.7 (8.5)	9.0 (4.0)	4.0 (1.0)	1.2	37.4 (40.1)
No Response	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.5)	0.2 (0.2)	0.9 (0.5)	0.0 (0.0)	0.7	2.1 (1.2)
Total	2.4 (10.4)	4.7 (11.3)	9.9 (15.1)	(14.2) (24.3)	28.6 (24.9)	24.3 (10.6)	10.9 (2.9)	5.0	100.0 (99.5)

N = 423
Adjusted N = 402

Top figure a Raw Percentage
Figure in Parentheses an Adjusted Percentage

Question: Provided high voltage electric transmission lines are not located on my property, I have no objection to having them built elsewhere.

TABLE 6-10

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.0 (0.0)	0.5 (0.5)	0.0 (0.0)	0.0 (0.0)	0.2	0.9 (0.7)
Agree	0.5 (2.0)	0.7 (1.7)	1.2 (1.7)	1.2 (2.0)	2.6 (2.2)	3.8 (1.7)	2.1 (0.5)	0.2	12.3 (11.8)
Neutral	0.5 (2.0)	1.4 (3.5)	2.4 (3.7)	5.2 (9.0)	7.8 (6.7)	5.2 (2.2)	3.1 (0.7)	0.9	26.5 (27.8)
Disagree	0.9 (4.2)	1.2 (3.0)	3.3 (5.0)	4.3 (7.2)	12.3 (10.7)	9.2 (4.0)	3.3 (1.0)	1.4	35.9 (35.1)
Strongly Disagree	0,5 (2.0)	1.2 (3.0)	2.6 (4.0)	3.3 (5.7)	5.2 (4.5)	5.9 (2.7)	1.9 (0.5)	1.4	22.0 (22.4)
No Response	0.0 (0.0)	0.2 (0.5)	0.2 (0.2)	0.2 (0.5)	0.2 (0.2)	0.2 (0.2)	0.5 (0.2)	0.7	2.4 (1.8)
Total	2.4 (10.2)	4.7 (11.7)	9.9 (14.8)	14.2 (24.4)	28.6 (24.8)	24.3 (10.8)	10.9 (2.9)	5.0	100.0 (99.6)

N = 423
Adjusted N = 402

Top Figure a Raw Percentage
Figure in Parentheses an Adjusted Percentage

Question: High voltage electric transmission lines should be constructed in areas where power lines currently exist.

TABLE 6-11

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	0.2 (1.0)	0.5 (1.2)	1.2 (1.7)	1.9 (3.2)	1.7 (1.5)	3.3 (1.5)	1.2 (0.2)	1.2	11.1 (10.3)
Agree	1.2 (5.3)	2.4 (5.7)	5.0 (7.7)	5.9 (10.2)	16.3 (14.2)	12.3 (5.5)	4.0 (1.2)	1.4	48.5 (49.8)
Neutral	0.2 (1.0)	0.9 (2.2)	2.1 (3.2)	3.3 (5.7)	6.1 (5.5)	5.7 (2.5)	3.1 (0.7)	0.9	22.5 (20.8)
Disagree	0.5 (2.0)	0.7 (1.7)	1.2 (1.7)	1.9 (3.2)	3.5 (3.0)	2.6 (1.2)	1.7 (0.5)	0.2	12.3 (13.3)
Strongly Disagree	0.2 (1.0)	0.2 (0.5)	0.2 (0.2)	0.7 (1.2)	0.7 (0.7)	0.5 (0.2)	0.9 (0.2)	0.5	4.0 (4.0)
No Response	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.5 (0.7)	0.2 (0.2)	0.0 (0.0)	0.0 (0.0)	0.7	1.7 (1.1)
Total	2.4 (10.3)	4.7 (11.3)	9.9 (14.7)	14.2 (24.2)	28.6 (25.1)	24.3 (10.9)	10.9 (2.8)	5.0	100.0 (99.3)

N = 423
Adjusted N = 402

Top Figure a Raw Percentage
Figure in Parentheses an Adjusted Percentage

Question: High voltage electric transmission lines should be built in relatively uninhabited areas of the state.

TABLE 6-12

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	0.2 (1.0)	0.2 (0.5)	1.2 (1.7)	2.6 (4.5)	2.6 (2.2)	1.4 (0.7)	0.2 (0.0)	0.7	9.2 (10.6)
Agree	0.2 (1.0)	2.4 (5.7)	2.8 (4.2)	4.5 (7.7)	10.2 (9.0)	7.3 (3.2)	6.9 (2.0)	1.7	35.9 (32.8)
Neutral	0.2 (1.0)	0.5 (1.2)	2.1 (3.2)	2.4 (4.0)	5.0 (4.2)	6.9 (3.0)	1.4 (0.5)	0.9	19.4 (17.1)
Disagree	1.4 (6.2)	0.5 (1.2)	2.1 (3.2)	3.1 (5.3)	7.3 (6.5)	6.1 (2.7)	1.7 (0.5)	0.9	23.2 (25.6)
Strongly Disagree	0.2 (1.0)	0.9 (2.2)	1.2 (1.7)	1.4 (2.5)	3.3 (3.0)	2.4 (1.0)	0.5 (0.2)	0.5	10.4 (11.6)
No Response	0.0 (0.0)	0.2 (0.5)	0.5 (0.7)	0.2 (0.5)	0.2 (0.2)	0.2 (0.0)	0.2 (0.0)	0.2	1.9 (1.9)
Total	2.4 (10.2)	4.7 (11.3)	9.9 (14.7)	14.2 (24.5)	28.6 (25.1)	24.3 (10.6)	10.9 (3.2)	5.0	100.0 (99.6)

N = 423
Adjusted N = 402

Top Figure a Raw Percentage
Figure in Parentheses an Adjusted Percentage

Question: High voltage electric transmission lines should only be constructed if they are designed to specifically serve Montana residents.

TABLE 6-13

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	0.5 (2.0)	0.9 (2.2)	1.7 (2.5)	2.4 (4.0)	2.8 (2.5)	4.3 (2.0)	0.9 (0.2)	0.9	14.4 (15.4)
Agree	0.9 (4.2)	1.9 (4.5)	4.0 (6.2)	5.2 (9.0)	13.2 (11.5)	6.6 (3.0)	2.6 (0.7)	0.7	35.2 (39.1)
Neutral	0.5 (2.0)	0.9 (2.2)	1.7 (2.5)	3.3 (5.7)	3.8 (3.2)	4.0 (1.7)	1.9 (0.5)	1.2	17.3 (17.8)
Disagree	0.5 (2.0)	0.7 (1.7)	2.1 (3.2)	3.1 (5.2)	7.6 (6.8)	7.6 (3.5)	4.3 (1.2)	0.9	26.7 (23.6)
Strongly Disagree	0.0 (0.0)	0.0 (0.0)	0.2 (0.5)	0.0 (0.0)	0.9 (0.7)	1.9 (0.7)	1.2 (0.2)	0.5	4.7 (2.1)
No Response	0.0 (0.0)	0.2 (0.5)	0.2 (0.5)	0.2 (0.5)	0.2 (0.2)	0.0 (0.0)	0.0 (0.0)	0.7	1.7 (1.7)
Total	2.4 (10.2)	4.7 (11.1)	9.9 (15.4)	14.2 (24.4)	28.6 (24.9)	24.3 (10.9)	10.9 (2.8)	5.0	100.0 (99.7)

N = 423
Adjusted N = 402

Top Figure a Raw Percentage
Figure in Parentheses an Adjusted Percentage

Question: Power companies should pay an annual fee to property owners whose lands are crossed by electric transmission lines.

TABLE 6-14

MONTANA ENERGY SURVEY

Income Category

	$0 to $2,999	$3,000 to $4,999	$5,000 to $6,999	$7,000 to $9,999	$10,000 to $14,999	$15,000 to $24,999	$25,000 plus	Income Level Not Specified	Total
Strongly Agree	0.5 (2.0)	1.9 (4.5)	2.4 (3.5)	3.8 (6.5)	8.7 (7.7)	5.0 (2.2)	3.3 (1.0)	2.1	27.7 (27.4)
Agree	0.9 (4.2)	2.6 (6.2)	4.7 (7.2)	6.6 (11.5)	13.7 (12.0)	12.1 (5.3)	3.5 (1.0)	0.7	44.9 (47.4)
Neutral	0.7 (3.2)	0.2 (0.5)	1.7 (2.5)	2.6 (4.5)	4.0 (3.5)	4.3 (1.7)	2.4 (0.7)	1.4	17.3 (16.6)
Disagree	0.2 (1.0)	0.0 (0.0)	0.9 (1.5)	0.7 (1.2)	1.4 (1.2)	2.1 (1.0)	1.7 (0.5)	0.5	7.6 (6.4)
Strongly Disagree	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.5)	0.7 (0.7)	0.7 (0.2)	0.0 (0.0)	0.0	1.7 (1.4)
No Response	0.0 (0.0)	4.7 (11.2)	0.2 (0.2)	0.2 (0.5)	0.0 (0.0)	0.2 (0.0)	0.0 (0.0)	0.2	0.9 (0.7)
Total	2.4 (10.4)		9.9 (14.9)	14.2 (24.7)	28.6 (25.1)	24.3 (10.4)	10.9 (3.2)	5.0	100.0 (99.9)

N = 423
Adjusted N = 402

Top Figures a Raw Percentage
Figure in Parentheses an Adjusted Percentage

The greatest social service impact may be expected in relation to housing, which is in short supply throughout the study area but particularly so in rural areas and small towns. The use of mobile homes and trailers can be expected to help offset shortages of permanent housing where the latter is not locally available. In rural areas and small towns, underdeveloped water and sanitation systems also contribute to housing problems since the number of new dwellings which can be satisfactorily accommodated is limited. Provided construction populations are either small or dispersed, schools, even those in rural areas, appear capable of absorbing additional students. Declining population in many of the counties has contributed to a general excess capacity in school facilities, although additional teachers may be necessary.

The distribution of population is a crucial variable in assessing the impact of a transmission line project on social service. In suggesting there would be relatively minimal impact, it is assumed that the population influx is distributed along a line segment. If the bulk of the population influx were to be located in a major urban area such as Billings or Missoula, existing delivery systems could easily absorb the anticipated increase. Additional construction personnel and their families would work an additional hardship in Rosebud County even if the population influx is small, given the already strained capacity of many social services in that county. Similarly, if the construction-related population influx were to largely locate in a small community such as Ryegate or Lavina, social services could be over-taxed. This latter condition is not considered probable given the organization of construction work, but it should be considered.

6.2.3.4. Summary

The discussion of this section suggests that the social impacts created by the possible construction of the 500 KV transmission lines from Colstrip to Hot Springs would be rather small. If construction crew size remains near the level projected by the Westinghouse report (1973), the anticipated population increase should not exceed an approximate maximum of 675 persons for each 110-mile-long segment of the line. Thus, existing community social structures should not be overwhelmed by newcomers, nor should they be radically changed by the temporary appearance of a transient construction population. Social service delivery systems appear adequate to handle any impacts that might be induced by the lines' construction. Major impacts, both short- and long-term, appear to be property damage, inconvenience, and nuisance impacts, especially to property owners along the transmission right-of-way, and aesthetic damage to the landscape.

This discussion is focused only upon the immediate impacts that can reasonably be expected to accompany the construction of the proposed lines. It should be noted that the presence of the lines may have consequences which could radically affect social life in Montana and its communities by stimulating additional industrial development within the state. Within the past decade, the Anaconda Company has investigated the possibility of opening new mining properties in the Heddleston Mining District near Lincoln and in Stillwater County near Nye. The Jonhs-Manville Corporation is currently investigating a mining property in the Beartooth Mountains. The search for resources suitable for industrial development is an on-going process within the state. The effect of construction of the 500 KV lines on further industrial development is open to speculation, but the availability of large quantities of electrical energy can certainly be considered a promotional factor.

6.2.4. Economic Impacts

The impact of the construction and operation of the two 500 KV lines from Colstrip to Hot Springs on local economic activity is difficult to assess for individual localities through which the lines might be built. For this reason the impacts are viewed in terms of the whole line and the entire state.

A number of possible economic impacts would be caused by the construction and operation of the proposed transmission lines. On the positive side there is the direct and secondary employment and income generated during the construction phase. Once built, the lines would provide a substantial source of tax revenue for those counties crossed by the lines.

On the negative side, construction activity and the physical presence of the towers limits the use of the land crossed. This is aggravated by the high percentage of guyed towers proposed. For typical guyed towers in level terrain, the four tower guy anchors form a square, 118' on each side (Westinghouse 1973).

The direct impact of the construction activity on the Montana economy would be due mostly to the local spending done by the influx of well-paid labor. It is expected that most of the labor would be from out of state, and most of the materials, likewise, would be imported. Some material (e.g. concrete) and some labor (e.g. clearing crews) would probably originate locally.

In order to estimate the impact of the construction of the lines on the local economy, a number of underlying parameters must be estimated. Assuming the materials used are not indigenous, labor input becomes the most important variable. Labor inputs themselves have to be broken down further if there are groupings which can be expected to exhibit different spending behavior. In addition, some assumptions about the local economy have to be made with respect to imported versus locally produced goods and services.

The labor input estimated here comes from multiple sources. Three estimates of total transmission line construction costs were made in Volume 2, Section 6.1.2.2. The middle estimate of $161,389,248 for the total costs of the two lines is used here. This figure is in mid-1974 dollars. In the applicants' analysis (Westinghouse 1973), construction costs of $85,444,000 were estimated. There is little detail provided as to what is and is not included in this figure; however, labor is estimated at 30% of the total. Since this estimate, inflation has increased the dollar costs greatly. Although the greatest increase has been in material prices, labor costs have also increased. The 30% share of costs allocated to labor is used here, yielding a total labor cost of $48,416,774.

In addition to the line construction costs of building the two lines from Colstrip to Hot Springs, there is also the cost of the associated substations at Colstrip, Broadview, Helena and Hot Springs. The substation costs are estimated at $35,073,000 of which 15% or $5,260,950 is estimated to be labor costs (Westinghouse 1973).

Combining the labor estimates, total labor cost is estimated to be $53,677,724. Take home pay would be much less than this, since this figure includes state and federal income taxes and fringe benefits. Assuming the employer's contribution to Social Security and other fringe benefits to be equal to 10% of the total labor cost, gross wages would then be $48,718,953.

Assuming gross income per worker at $15,000 per year, take home pay would range from about $10,883 for a worker with no dependents upward, depending on the number of dependents claimed. If it is assumed that the typical worker claims two dependents in addition to himself, he will pay about $1,985 in Federal income tax, $600 in state income tax and $772 in Social Security contributions. These tax figures are based on 1973 tax forms; the Social Security payment is based on 1974 figures.

Based on this split of the $48,718,953 gross wages, federal income taxes will account for $6,447,141, Social Security payments will amount to $2,507,402, state income tax will take an additional $1,948,758 and the remaining $37,815,652 will be the approximate take home pay (less any employee contributions to health insurance, retirement, etc.).

In order to calculate the secondary income created by the primary construction employment, additional information is needed on local spending behavior and the percentages of purchases that are spent on local and imported goods and services. The assumptions made in the applicants' analysis (Westinghouse 1973) are used here. These assumptions are as follows:

1) The labor force is made up of 20% state residents and 80% from out of state.

2) Of the 80% nonresidents, 40% will bring their families with them.

3) Those accompanied by families (the 20% residents and the 40% of the 80% nonresidents) will spend 70% of their budgets locally, and those without families will spend 35% of their budgets locally.

4) Of the total local expenditures, 40% will be for locally derived goods and services.

From these assumptions a kind of local income multiplier can be calculated. Assume the local merchants exhibit the same spending behavior as the nonresidents with families and the resident line workers (3 above). This will yield for each dollar of take home construction pay to residents or nonresidents with families, an additional .389 dollars of local secondary income. The multiplier for nonresidents without families will be half as large or .194. These multipliers do not take into consideration taxes and social security contributions beyond the construction workers. The effect can be expected to be minimal.

The results of these assumptions are shown in Table 6-15. Secondary income is $11,170,745, and if added to primary gross pay (before taxes) would yield a total income impact of $59,889,698. Of this total, $20,914,536 ($9,743,791 for resident construction workers and $11,170,745 in secondary income generation) would be income to

TABLE 6-15

DETERMINATION OF LOCAL INCOME IMPACT

Labor Category	Take Home Pay	Secondary Multiplier	Secondary Local Income Generated
Resident	$ 7,563,130	.389	$ 2,942,058
Nonresident with Family	12,101,009	.389	4,707,293
Nonresident without Family	18,151,513	.194	3,521,394
Total	$ 37,815,652		$ 11,170,745
		Plus gross primary wages	48,718,953
		Total impact on income	59,889,698
		Less income to nonresidents	38,975,162
		Total income to residents	$ 20,914,536

the local population and $38,975,162 would be paid to nonresidents.

State income taxes flowing from the construction payroll would be about $1,950,000. This figure is based on the typical worker earning $15,000 per year and having two dependents in addition to himself. State income taxes derived from secondary income would be much less for two reasons. First, the absolute size of secondary income is much smaller and second, the percentage of income paid in taxes would be smaller because the wages per worker would be substantially smaller (the Montana income tax rates are progressive, i.e., they increase as the income itself increases).

The other large positive impact of the transmission lines would be the increase in property taxes that would come from the lines. In order to estimate the property taxes that would be paid on the transmission lines, a number of simplifying assumptions must first be made.

In Montana, all of an electric utility company's property is taxed as a single unit, and it is very difficult to estimate what the contribution of any single piece of the total plant is to the total company assessment. An additional complication in this case is that the lines may be owned by five separate companies.

In evaluating the total property of a utility, three things are considered. These are: 1) the current price of the company stock, 2) current earnings of the company and 3) actual cost of plant equipment the company owns. In order to estimate property taxes on the lines alone, it is assumed here that the contribution of the lines and the substations to total property assessment is their original cost: $196,462,248. This figure is then multiplied by a .40 equalization factor and again by .40 (Class 9 utility property) to yield an equalized taxable value of $31,433,960. In reality this figure would be prorated between the various counties in which the lines were located. Individual county mill rates would then be levied on each counties share of the $31,433,960. This procedure has been bypassed here and the average 1974 mill levy for all counties has been used. This levy is 210 mills and yields an estimated annual property tax on the lines of $6,601,132.

6.3. Impacts of Alternate Corridors

The corridor selection process attempts to align utility corridors in such a manner as to minimize adverse environmental impacts and interference with land uses, while at the same time allowing for maximum system reliability and proximity to load centers. One important consideration in the evaluation of alternate routes is the amount and type of land use which would be affected by the construction and physical presence of the utility structure. Certain types of land use, such as urban areas and irrigated lands, may be more incompatible with high-voltage transmission lines than other types, such as rangeland. This section presents a tabular comparison of land uses along each of several possible routes for the proposed Colstrip-Hot Springs twin 500 KV transmission lines.

The accompanying Alternative Corridors map overlay located at the back of this volume shows the location of the MPC preferred route for the proposed transmission line, alternative MPC corridors, and several preliminary Energy Planning Division (EPD) corridors. The EPD corridors shown are not necessarily those which will be recommended by the EPD in the final environmental impact statement; the final recommendation will be based upon further analysis of environmental impacts and upon public comment (see Section 7.4.).

In Table 6-16 the approximate number of square miles of several types of land use which would be crossed by the two-mile wide corridor segments is listed for each corridor segment shown on the map. These figures are based on the land use inventory maps prepared for this study. Much detail, including many isolated areas less than 160 acres in size, was lost during the process of reducing the rough maps (prepared at a scale of 1" = 2 miles) to the working maps (which were at a scale of 1" = 12 miles). Therefore, in this general comparison, areas were estimated only to the nearest square mile.

It should be realized that the figures given are for a two-mile wide corridor, while the actual corridor right-of-way is a width of 300 feet. The centerline of the 300-foot corridor will be located within the final two-mile corridor so as to minimize negative impacts and interference with land uses. Thus, for a corridor segment which includes several square miles of dry cropland, for example, proper centerline selection may in some cases reduce the actual amount of dry cropland affected to nearly zero.

6.4. Recommended Procedures to Minimize Impacts

6.4.1. Construction

6.4.1.1. Survey

1) Restrict cross country travel, especially on croplands and fragile soils.

2) Minimize clearing and keep it within areas to be cleared later.

3) Use helicopters and existing roads to the maximum extent possible.

4) Minimize flagging, aerial survey targets, and other similar materials. Insure they are removed before final project completion.

5) Assign state and federal environmental control inspectors to project while in this phase. These inspectors can watch for compliance with the above guidelines. They can also influence tower and centerline locations of transmission lines and roads. Such changes are more easily made during this stage. These inspectors should remain until the project is completed.

6) Design for minimum roads, clearing, special sites, etc.

TABLE 6-16

Comparison of Alternate Corridor Segments

Segment	Length (mi.)	Area (sq.mi.)	Land Use Categories Affected (sq. mi.)[1]						
			Urban	Small Communities	Irrigated Land	Dry Cropland	Woodland[2]	Range-land	Scattered Built-up Areas
A-1	72.5	145	0	0	4	4	97	40	0
A-2	39.0	78	0	0	1	0	69	8	3
A-3	24.0	48	0	0	6	3	7	32	3
A-4	13.5	27	0	0	0	1	7	19	0
A-5	46.5	93	0	0	16	1	8	68	3
A-6	67.0	134	0	0	48	20	5	61	16
A-7	68.0	136	0	Tr[3]	22	20	6	88	30
A-8	60.5	121	0	0	8	4	21	88	5
A-9	40.0	80	0	0	0	11	11	58	0
A-10	27.5	55	0	0	0	32	2	21	14
A-11	44.0	88	0	0	12	15	12	49	3
A-12	22.5	45	0	0	4	4	11	26	5
A-13	77.5	155	0	0	4	14	33	104	5

TABLE 6-16

Comparison of Alternate Corridor Segments

			Land Use Categories Affected (sq. mi.)[1]						
Segment	Length (mi.)	Area (sq.mi.)	Urban	Small Communities	Irrigated Land	Dry Cropland	Woodland[2]	Range-land	Scattered Built-up Areas
B-1*	15.5	31	0	0	5	3	0	23	4
B-2	18.0	36	0	0	7	2	1	26	2
B-3	19.5	39	0	0	11	0	3	25	6
B-4	52.5	105	0	0	7	0	88	10	0
B-5	10.5	21	0	0	1	0	4	16	0
B-6	9.5	19	0	0	2	0	1	16	0
B-7	8.5	17	0	0	1	0	0	16	1
B-8	13.0	26	0	0	0	0	15	11	8
B-9	27.0	54	0	0	12	2	14	26	0
B-10	6.5	13	0	0	1	0	1	11	0
B-11	3.5	7	0	0	0	0	6	1	0
B-12	8.5	17	0	0	2	0	11	4	0
B-13	8.0	16	0	0	3	0	8	5	0
B-14*	9.5	19	0	0	0	0	2	17	0
B-15	14.0	28	0	0	0	0	27	1	0
B-16	9.5	19	0	0	0	0	17	2	1
B-17	42.0	84	0	0	11	3	30	40	0
B-18	13.0	26	0	0	0	0	19	7	0
B-19	8.5	17	0	0	0	0	6	11	0
B-20*	40.5	81	0	0	6	6	14	55	0
B-21	35.0	70	0	0	13	4	8	45	0
B-22*	27.0	54	0	0	5	4	17	28	0
B-23	18.0	36	0	0	3	2	17	14	0
B-24	56.0	112	0	0	0	22	14	76	0
B-25	20.5	41	0	0	0	3	10	28	0
B-26	14.5	29	0	0	7	14	0	8	0

TABLE 6-16

Comparison of Alternate Corridor Segments

			Land Use Categories Affected (sq. mi.)[1]						
Segment	Length (mi.)	Area (sq.mi.)	Urban	Small Communities	Irrigated Land	Dry Cropland	Woodland[2]	Range-land	Scattered Built-up Areas
B-27	32.0	64	0	0	8	0	26	30	0
B-28	48.5	97	0	0	0	25	7	65	0
B-29*	25.0	50	0	0	0	15	5	30	0
B-30	10.0	20	0	0	0	0	0	20	0
B-31*	21.0	42	0	0	0	3	7	32	0
B-32	78.5	157	0	0	4	3	15	135	0
B-33*	63.5	127	0	0	1	4	33	39	0

TABLE 6-16

Comparison of Alternate Corridor Segments

Segment	Length (mi.)	Area (sq.mi.)	Land Use Categories Affected (sq. mi.)[1]						
			Urban	Small Communities	Irrigated Land	Dry Cropland	Woodland[2]	Range-land	Scattered Built-up Areas
C-1	12.5	25	0	0	6	4	2	13	0
C-2	9.0	18	0	0	9	0	0	9	0
C-3*	23.5	47	0	0	5	0	27	15	0
C-4*	14.5	29	0	0	0	0	27	2	0
C-5	15.0	30	0	0	14	0	2	14	1
C-6	5.5	11	0	0	0	0	9	2	0
C-7	19.5	39	0	0	0	0	33	6	0
C-8	104.5	209	0	1	33	5	25	144	0
C-9	56.0	112	0	0	5	1	53	53	0
C-10*	26.5	53	0	0	1	7	0	45	Tr
C-11	29.0	58	0	0	3	6	3	46	0
C-12*	76.0	152	0	0	8	35	29	80	0

TABLE 6-16

Comparison of Alternate Corridor Segments

			Land Use Categories Affected (sq. mi.)[1]						
Segment	Length (mi.)	Area (sq.mi.)	Urban	Small Communities	Irrigated Land	Dry Cropland	Woodland[2]	Range-Land	Scattered Built-up Areas
D-1*	21.0	42	0	Tr	29	0	0	13	20
D-2	7.9	15	0	0	1	1	1	12	2
D-3*	10.5	21	0	0	0	0	20	1	4
D-4*	39.0	78	0	0	9	2	55	12	0
D-5*	10.5	21	0	0	4	3	2	12	0
D-6	21.0	42	0	0	2	1	29	10	0
D-7	13.0	26	0	0	2	0	19	5	0
D-8	32.0	64	0	0	0	0	40	24	0
D-9	36.0	72	0	0	4	0	42	26	0
D-10	49.5	99	0	0	2	23	10	64	0
D-11	54.0	108	0	0	3	4	33	68	0
D-12	84.5	169	1	0	5	73	1	89	8
D-13	21.5	43	0	0	0	7	1	35	0
D-14	83.0	166	0	0	2	70	0	94	0
D-15	32.0	64	0	0	5	34	1	24	0

[1] All categories are mutually exclusive except for scattered built-up areas.
[2] Includes commercial and noncommercial woodland.
[3] Tr= trace

* MPC preferred route.

6.4.1.2. Clearing

1) Clear to minimum requirements rather than maximum.

2) Comply with the Environmental Criteria for Electric Transmission Systems issued by U.S. Departments of the Interior and Agriculture. These criteria are broad enough to be applied throughout the line length.

3) Combine special sites such as reel sites, staging areas, tower sites, and roadways to the maximum extent possible.

4) Sell all merchantable timber and dispose of slash by complete burning in air-curtain burners or other aesthetic approaches, such as chipping, burying or removal.

5) Limit cross country equipment travel.

6) Plan construction to avoid needless or repeated clearing.

7) Try to avoid narrow ridgetops and steep slopes for tower sites, especially angle or dead end towers.

8) Use the smallest equipment that will do the job.

9) Cut stumps to within three inches of the highest ground.

10) Leave all low-growing vegetation except where essential for complete removal such as at footing locations.

11) Where possible horses, hand methods, or small power tools should be used for clearing.

12) If heavy equipment is used, some removal of topsoil will be unavoidable. Therefore topsoil removed during construction should be stockpiled and replaced after construction.

13) Long tunnel views of transmission lines crossing highways in wooded areas, down canyons and valleys or up ridges and hills should be avoided. This can be accomplished by having the lines change alignment in making the crossing, or in other situations by concealment of terrain or by judicious use of screen planting.

14) In clearing and construction operations, avoid contact with stabilized talus slopes and other prominent rock exposures. Talus slopes become unstable if disturbed and even slight disturbances in lichen-covered rock can leave a highly visible scar.

6.4.1.3. Road Construction

1) Use state highway and U.S. Forest Service road design and construction criteria for permanent roads. Use minimum

standards required for the type and use of road. Temporary roads should also be designed to prevent erosion.

2) Design for the traffic and equipment to be used, single lane.

3) Try and combine permanent roads with other transportation plans such as county or federal agency needs.

4) Minimize all roads.

5) Install proper drainage and base material.

6) Avoid encroachments near rivers or live streams. When crossing, use bridges or culverts.

7) Trees, shrubs and grass not cleared should be protected from damage during construction.

8) Terraces and other erosion control devices should be constructed where necessary to prevent soil erosion on slopes on which rights-of-way are located without undue delay.

9) Where rights-of-way cross streams or other bodies of water, the banks should be reclaimed and stabilized to prevent erosion.

10) Top soil should be stockpiled and spread on road cuts prior to reseeding.

11) Road locations should be to one side of right-of-way, enabling traffic to avoid cables and conductors during the wire stringing operation. Necessary crossings of right-of-way centerline should be near towers for the same reason.

12) Specifications for gates, cattle guards and bridges should be included in the road construction contract.

13) Avoid off-road travel by vehicles.

14) Construct temporary roads on the levelest terrain, even if this requires significant departures from the right-of-way, and especially if the total amount of excavation is reduced.

6.4.1.4. Tower Erection

1) Utilize helicopters to the maximum possible.

2) Use the smallest ground equipment that will do the job.

3) Carry out crane pad construction with the crane crew--not the clearing crew. Do not construct crane pads on level ground.

4) Require hand excavation in highly sensitive or fragile areas.

5) Install guy anchors and counterpoise equipment carefully to restrict disturbances to a small area.

6) Concrete batch plant sites are areas of high use; therefore, provisions for sanitary facilities and waste disposal should be made at each of these sites. Also, sites should be chosen that have adequate water supplies.

7) Tower sites should be chosen to minimize disturbance of agricultural land.

6.4.1.5. Conductor Stringing

1) Lift tower electrical hardware by pulling with winch rather than cross-country vehicle.

2) Fly in sockline by helicopter.

3) Insure all guard structures are installed including protection to small items such as fences prior to sockline pulling.

4) Make sure clean up is thorough and proper to avoid animal "hardware" poisoning or injury.

5) Mutually locate and agree on pulling sites and splice points at the same time tower sites are staked.

6) Use self-propelled spacing buggies (wire trollies used to install spacers on conductors).

6.4.1.6. Final Clean Up and Restoration

1) Conduct a thorough and complete clean up.

2) Restore all soils and vegetation to as near the original condition as possible.

3) Have qualified subcontractors reseed and revegetate, doing so at the proper time of year and with adaptable native species.

4) Order sufficient seeds and fertilizer very early. Specify in the contract the percent purity germination and inert material.

5) Plan excess earth material disposal mutually and early.

6) Install erosion bars wherever needed.

7) Repair fences and gates and repair and clean cattle guards.

8) Close, seed, and otherwise restore all temporary roads.

9) Complete slash disposal as needed.

10) Bring all permanent roads up to proper standards for future maintenance.

6.4.2. Maintenance

1) Allow no herbicides or insecticides.

2) Perform vegetative management to minimum safety and operation standards with minimal impact equipment and procedures, such as small machines and hand held devices.

3) Promote planting of low growth native vegetation. Grasses and shrubs introduced should be compatible with existing plant communities and usable by wildlife and/or livestock.

4) Minimize maintenance roads and helicopter landing sites.

5) Inspect for environmental damage or inadequate restoration and correct defects.

6) On agricultural lands, maintenance should be performed in a manner to reduce crop or pasture damage.

6.4.3. General

1) Obtain a complete list of equipment types, crew sizes, and planned construction sequence.

2) Comply with all local, state, and federal environmental and sanitary requirements.

3) Comply with U.S. Forest Service and BPA construction guidelines throughout the line length. Use these as a model for state and private lands.

4) Require a complete maintenance plan and agree on procedure allowable.

5) Make utility responsible for correcting all latent defects to roads, fences, gates, crops, excavation, restoration, and other construction or maintenance activities for a period beyond the end of construction for at least five years and preferably for the entire lifetime of line.

6) Brief all contractor supervisors and employees on environmental constraints prior to and during construction orally and written. Formally and informally. Post such reminders on job sites.

7) Have sufficient technically qualified engineering inspectors on the ground from the beginning with authority to enforce compliance if necessary to protect the environment.

8) Explain that unwarranted damage, particularly in earthmoving, will be cause for contract extension and additional cost as the line must be constructed with minimal environmental degradation.

9) Government officals of cities and counties along the transmission line route should be given advance notice of the

phases of construction, the crew size anticipated for each phase at that locale, the period and length of time that the crews will be in the vicinity, and an estimate of the number of school children accompanying the crews.

FOOTNOTES

CHAPTER SIX

1. The potential effects of inversions were not considered; therefore "maximum" refers only to conditions of unlimited atmospheric mixing.

2. Averaging times were not reported in the paper. A one-hour averaging time may be inferred from the source of dispersion coefficients sited by Scherer et al., which was ASME, 1968.

3. Again, the averaging time was not reported. Since the source of dispersion coefficients was also ASME, 1968, the reported concentrations are probably hourly averages.

4. The dimensions of the box were defined by the circular horizontal area and a vertical distance of 1 km.

5. The three areas included: 1) a circular region of 81 km radius in West Virginia encompassing eight generating plants; 2) a circular region of 81 km radius center at the Four Corners generating plant in northern New Mexico; and 3) an 18 km radius region in Los Angeles centered on the intersections of three major transmission lines.

6. An elevated temperature inversion tends to act as a "lid" because it inhibits the vertical exchange of air between air layers above and below the temperature discontinuity. A temperature inversion could therefore cause the buildup of pollutants emitted from low level or low buoyancy sources located beneath it. However, the Oak Ridge report did not cite evidence that an actual inversion was having such an effect on ozone emitted from the transmission line.

7. These assumptions are the same as those used to estimate the size of construction-related population increases in Rosebud County at the power plant site (Section 11.2.2.1., Volume 3B).

8. See also Westinghouse (1973), Section 3.7.1.6.

CHAPTER SEVEN Long-Term Impact Considerations and Information Dissemination

7.1. Adverse Impacts Which Cannot Be Avoided

Any action creates certain impacts, some of which are adverse, upon some portion of the environment. The impacts of transmission lines are diverse and varied, as shown in earlier parts of this report; however, many of these impacts can be avoided by changes in line design, even though the design may be made more expensive. This section will briefly summarize those impacts which cannot be reasonably avoided if the lines are constructed.

7.1.1. Aesthetic Impacts

Unless the line is placed underground, which is not a reasonable alternative at this time, the towers and conductors will be aesthetically unpleasing to many persons. Aesthetic impacts include, but are not limited to, visual impacts. The presence of a man-made object in an otherwise wild part of the state offends many people. Large transmission lines are symbols of different things to different people. Some view the thin strands of metal as a web connecting the lives of distant persons, while others may view the lines as symbols of man's "progress" in "conquering nature"--a symbol perhaps more widely accepted in earlier times. To some persons, the transmission lines are an ugly obtrusion into a pure natural environment--a symbol of modern man's arrogance and his disharmony with nature.

Aesthetics is a personal but viable entity which gives man his humaness. Because aesthetic impacts are personal, they cannot be quantified or unanimously agreed upon. But for many persons, the design and placement of the line does affect the impact.

Most persons live, work, and travel near distribution lines, highways, railroads, and other man-made features. The aesthetic impact of a transmission line along a highway is quite different from one over a pristine mountain. One school of thought is that lines should be built along areas such as highway corridors already strongly affected by man. The lines would therefore not affect more natural areas. An opposing school of thought examines the number of persons who must view the lines and would prefer to have them hidden. If the lines are built, no matter which school of thought is followed, some people would be offended. Where a line can be built along existing corridors but out of sight of residents and travelers (and many parts of Montana allow this compromise), the least impacts may result.

Careful tower design and the use of non-specular coatings on towers and conductors reduce aesthetic impacts, but there is no consensus on what constitutes a "pretty" tower.

7.1.2. Land Use Changes

The presence of a transmission line affects land use. Certain activities are restricted in the right-of-way, and agricultural and timber production is reduced.

The proposed lines would be some 430 miles long and require a 300 foot right-of-way, committing a total of 15,636 acres. Although this land would not become useless wasteland, certain potential activities and some production would be lost. The spatial limits of environmental impacts are not those of the right-of-way; some impacts, such as the area taken out of production by the towers, are limited to a small part of the right-of-way, whereas others, such as those caused by some form of pollution, extend well beyond the boundaries of the right-of-way. As a lineal feature of the landscape, the lines could serve as a partition to some activities, therefore subtly affecting a much larger area. The support towers interfere with farm machinery, and tall equipment such as drilling rigs could not be used under the lines. It is best that houses and other such structures not be built in the right-of-way. In forested areas, tall trees would be removed and kept from growing back, although shorter trees may be allowed and some economic benefits may be realized.

Such electrical effects as induced ground current and radio interference are unavoidable in themselves and further act to restrict activities near the line.

7.1.3. Use of Natural Resources

Building the transmission line would require the use of a number of natural resources. The manufacture of the towers and conductors requires additional resources and creates pollution. This subject will be treated in Section 7.2.

7.2. Irreversible and Irretrievable Commitment of Resources

Construction of the proposed Colstrip project would directly and indirectly commit vast quantities of resources. Except for some material that may be salvaged and recycled into other uses (such as the copper and some of the steel), most of the resources are irreversibly committed. The materials that actually make up parts of the plant constitute only a portion of the total commitment.

7.2.1. Energy

Although the proposed project is an energy converter, energy is used in building and operating the plant. Since data are unavailable to quantify energy expenses, the topic will be treated qualitatively.

Of the total energy expended in the creation of Units 3 and 4, most will be consumed in mining, processing, and manufacturing the materials that will physically make up the plant. The thousands of tons of steel, wire, pipe, concrete and other materials must be transported to the site and assembled. Transportation consumes energy, the amount depending upon the type of conveyance and distance covered. On site, energy is used to handle and assemble the various materials.

The total energy consumed is expended in many complex systems. The manufacture of Portland cement used to make the concrete structures is one of the simpler examples. Clay, limestone, and other materials are mined by power equipment using electricity and petroleum products. The raw materials are then transported to that cement plant which requires energy. In the plant, the materials are handled repeatedly in the crushing, grinding, and blending prior to firing in a kiln. The kiln uses large amounts of energy derived from coal, oil, or gas to raise the temperature of the raw materials to about 2600° to 3000° F. The product is further handled and finally shipped to the buyer. Additional energy is used in pollution control at the cement plant. The building and maintenance of the equipment in the mines and plant further add to the energy commitment of the finished Portland cement. Similar but more complex systems provide the copper, stainless steel, and other materials that go into the power plant. Construction of the Colstrip project would result from great expenditures of energy in other portions of the industrial sector of our society.

Once built, the plant would continue to depend upon energy to operate, much being derived from the plant itself. Coal mining uses electric and diesel-powered equipment. At present rates, the energy to mine the coal costs 10.2¢ per ton which breaks down to 3.4¢ for electricity and 6.8¢ (.23 gallons) for fuel oil. The figure does not reflect energy costs of building the mining equipment. Auxillary power requirements of the plant are about 78 megawatts per unit or about 11% of the total output. Most auxillary power is needed to operate the pollution control equipment. A question arises as to how much net energy the Colstrip project would produce in light of the requirement of more such plants in the future. Although the Colstrip project cannot replace the energy used to build it, the project would contribute to the building of future power plants if electrical generation capacity continues to grow. The building and operation of future power plants will generally rely upon lower grade mineral deposits (including fuels), many located in remote parts of the earth. The increased transportation costs and more sophisticated technology needed to utilize these deposits, and to control pollution in the conversion and manufacturing of the materials used in future power plants will increase the total energy costs of each new plant.

7.2.2. Non-Renewable Resources

The non-renewable resource costs of the Colstrip project are as complex as the energy costs. The plant itself would use some 45,000 tons of steel, 94,000 cubic yards of concrete, over 1100 miles of wire and cable, and over 100 miles of pipe plus much more material in various components. Some six million tons of coal would be needed each year to operate the plants if they are constructed. The transmission lines would require about 40,000 tons of steel for the towers, 34,000 tons of steel and aluminum for the conductors, and 600,000 insulators plus an undetermined amount of concrete and other materials. Still other materials are used in manufacturing and processing the materials that actually go into building the plant and transmission lines.Metallurgical grade coal and limestone are used in steel production. Steel is used to produce some copper. Coal, oil, and natural gas are used to provide energy in the manufacturing processes. Oil is also used to produce a variety of necessary materials including plastics. Metals and energy from fossil fuels become mining equipment that provide the metallurgical coal for steel production that goes into the Colstrip plant and transmission lines, and so on. The exact amount of non-renewable resources needed to build the Colstrip project is impossible to figure, because, when considered in total, the Colstrip project becomes an indistinguishable part of the entire industrialized system.

The use of non-renewable resources is of consequence in that as the finite supply is consumed, future use will depend upon poorer, less accessible deposits and/or reliance upon more sophisticated technology for resource recovery.

7.2.3. Timberland Agricultural Products Lost

Timber and agricultural products are renewable, and land use changes, in many cases, are reversible; however, products not grown are lost and cannot be replaced. A field of wheat not harvested because of construction activity is an irreversible loss of that field's production for that year.

Loss of biological production would result from long-term land use changes at the plant site, at the mine, and along the transmission lines, and short-term land use changes would result during construction of transmission lines and pipelines, and coal mining (if reclamation is successful). Pollution and electrical effects could reduce biolgoical production in the vicinity of the plant and transmission lines.

7.3. Long-Term Considerations of the Proposed Colstrip Project

Both individually and collectively, people tend to view the world on a short-term basis. Consideration of long-term effects of their actions plays a small role in decision-making. Similarly, people place more emphasis on local situations than upon national or global ones. Thus long-term, global implications of a particular action have the least weight in decision making (Meadows et al.1972).

A large power complex, such as the one proposed for Colstrip, has both long-term and national (and global) implications. Since these wider-ranging effects are different from the local, short-term connotations, some attempt must be made to evaluate the proposal to build the facilities in light of the long-term effects.

In recent decades, man has experienced rapid growth of scientific knowledge and technological innovation. The great expansion of knowledge in these areas has strongly influenced the evolution of twentieth century civilization. Although not all of this change has been detrimental to mankind, neither has it been totally beneficial. All too often, major social, political, and economic changes have accidentally (not planned) come about as a result of technological change. Mankind follows the paths of latest inventions with little thought as to where all these paths will eventually lead. Technological feasibility has become the determining factor in decision making. What can be done takes precedence over what should be done (Dubos 1970).

This type of thinking, which might be called the progress ethic, was exemplified by Eric Walker in a newspaper article during the debate over funding an American supersonic transport (1971). His thesis was that the U.S. will someday have an SST because: 1) it is technically possible, 2) the Russians already have one, and 3) "just ridiculous" environmental concerns would be overcome by the engineers. He completely ignored the basic question of whether an SST is desirable and should be developed.

7.3.1. Montana Considerations

Unlike land, which can produce crops and provide a living for many generations, a power plant has a rather short life. Likewise, the coal deposit, once mined, is depleted forever. The tax base and jobs provided by the Colstrip project would be transient. Continued taxes and jobs past the life of the plant would be dependent upon other industry situated in the area and agriculture.

Persons who would fill the newly created jobs are not necessarily those living in Montana at present. Unemployment in other parts of the nation besides a desire to live in Montana (because of its uniqueness) could cause great numbers of people to immigrate to the state.

Children of the immigrants of coal development may well out-number the jobs available in 30 to 50 years. Unemployment may be much higher than at present as the power plants are phased out resulting in large numbers of persons (who would then be long-time residents) being forced to leave the state.

An alternative to this scenario would necessitate continued industrial development in eastern Montana. Continued long-term industrialization to maintain employment and a tax base has even more profound effects which cannot be evaluated at this time. Pittsburgh, Pennsylvania, a heavily industrialized urban area, obtained much of its character from the rich coal deposits in the area. Although Rosebud County will probably never duplicate Pittsburgh, the two areas may share some characteristics if large-scale coal development proceeds.

Although long-term effects of the Colstrip project are difficult to evaluate, we must not allow the possibilities of technology and the promise of short-term benefits to lead us unwittingly in directions that may prove to be detrimental. The implications of such decisions must be well analyzed, and the choice we make for the future of our state must be with full realizations of the consequences.

7.3.2. National and Global Considerations

Much of the world has become industrialized in the past one and a half centuries. Factories and large industrial communities have sprung up in many countries. Mechanized agriculture, which requires fewer persons to feed the society, and the need for more manpower in the industrial sector have caused large population shifts from rural to urban environments. With industrialization came shorter work weeks and a greater supply and variety of consumer goods and services. Better medical care and abundant food allowed the population to grow to increasingly higher levels. In providing material goods, security, and comfort, industrialization has worked very well in the United States. Based upon consumption of resources, the United States is outstanding. With only 6% of the world's population we consume about one-third of the world production of raw materials and energy (Singer 1970).

Industrialization, in the context used above, is a complex process involving all aspects of society. Social, economic, political, and technological systems have changed or grown in the process. Especially in the twentieth century, technology and highly technological systems, which have accounted for much of industrialization's success, have grown enormously.

The lifestyle enjoyed by the majority of Americans in the 1970's is one of relative security, comfort, leisure, and an abundance of material commodities. It is also totally dependent for its existence upon a large number of highly complex systems. Combined in a mutually interdependent manner, these complex systems form a higher order system (supersystem) that not only provides our amenities but keeps us alive by providing our basic needs. Very few people grow their food, make their clothes, build their homes, or collect the fuel to heat those homes. Even today's farmer generally buys much of his food at a supermarket.

The supersystem feeds and grows upon itself with the help of several contributing factors: 1) increasing population, 2) growth per capita consumption, 3) increasingly complex systems to produce the raw materials and products to sustain high populations and per capita consumption, and 4) increasingly complex systems to remedy the ill effects of the producing systems. These four factors will be analyzed separately.

The population of the world is rapidly growing. The approximately 3000 million world population in 1970 may double by year 2000 (Meadows et al. 1972). Even in the United States, where birth rates have fallen to levels that, if continued, would result in zero population growth, the population will continue to grow for several decades before leveling off. Based on estimates using the lower fertility rate (U.S. Department of Commerce 1973), the United States population will grow from 204 million in 1970 to 264 million by 2000 and 297 million by 2020.

Additional persons require more food, more housing, and more services. To double world food production would require basic changes in agriculture, with resultant social and economic changes (MIT 1970). But supposing these changes could be made and such innovations as the high yield strains of grain would produce as originally expected, the increased supply of food would be inadequate within several decades if the world population continues to grow at the present rate. Increased agricultural production has been accomplished by mechanization and the increased use of energy and chemicals. This trend makes the agricultural producer more dependent upon the systems which provide his machinery, fuel, fertilizer, and other commodities. More people put more stress on the systems which provide housing, transportation, medical services, and so forth. These systems ultimately demand more energy, minerals to build additional schools, hospitals, transportation systems, and the like. As long as resources remain abundant, a growing economy can accomodate the population growth, but as resources become scarce, shortages and inflation occur.

An increase in per capita consumption places demands upon the producing systems just as increasing population does. Most people aspire to have more goods, services, and comfort regardless of what they already have. This aspiration makes itself felt in union halls and voting booths, resulting in business and governmental response which further adds to the growth of the supersystem.

Raw materials, especially non-renewable resources, are limited in amount. As the easy-to-get materials are consumed, more sophisticated techniques are required to obtain more. Agricultural products, timber, and mineral resources all share this characteristic. To produce more corn, more marginal land must be farmed using special hybrid seed, more fertilizer, insect- and weed-killing chemicals, and energy in planting, harvesting, and transportation. To produce more oil, remote and marginal fields must be brought into production. These fields require deeper drilling, off-shore drilling, or extensive transportation networks. The oil resources such as those found by observing seeps and recovered by the primitive devices available to Colonel Drake in 1859, are mostly depleted. Instead, oil is found and obtained at sea and in the Arctic by incredibly expensive techniques, using sophisticated technology, and many men and materials.

Large-scale production brings many kinds of environmental degradation, including pollution. Many industrial processes produce waste or allow materials to escape into the environment as pollutants. Processes which consume electricity, but are otherwise pollution free, merely transfer the emission of pollutants from the factory to the power plant. Since the atmosphere, land, and water of this planet are finite, pollutant levels tend to rise with greater production. To avoid severe environmental damage, technology has been applied to control pollution. In some cases, where a usable product is the pollutant, an economic saving can be realized from control; in most cases, pollution control is expensive. Sophisticated equipment and additional energy requirements increase the costs of production. Without pollution control, the costs are in the form of damage to human health and natural resources. Pollution control adds to the complexity of the producing systems and increases consumption of resources.

Many persons in our society believe that all problems can be solved by technology, and, consequently, that population and economy can grow without limit by continued application of new technology to solve the problems that arise. A glance at history serves this point of view well. For example, if we had to depend on wood for our fuel as our ancestors did, we would have frozen to death many years ago. Large power plants, ocean-going supertankers, and nuclear reators could not be foreseen in 1840. However, technological innovations do not always work as planned, as problems with "miracle" strains of grain, DDT, Egypt's Aswan Dam, and some modern rapid transit systems attest.

More advanced technology in a given area usually depends upon other systems which in turn require more technology. As the supersystem becomes more complex, economic and social perturbations become greater threats to the whole and each technological breakthrough becomes more essential. As the sophisticated and complex society becomes more dependent upon all of its systems, the risks involved in an incorrect political decision, economic depression, social upheaval, or war become enormous. Since personal survival is dependent on the supersystem for basic needs as well as maintenance of the life style, a strong perturbation could initiate additional social, political, and military disruption which might hasten the collapse of society. In this case, prolonged dependence upon advanced technology, if it adds to the fragility of the system, would be detrimental. The disaster initiated by the drought in the Sahel demonstrates that the reality of this kind of catastrophe is not a piece of science fiction (Wade 1974). Although the Sahelian problem was geographically isolated, a similar collapse could occur in the more advanced countries, made more likely by the strong interdependence of many countries and the threat of global nuclear war.

V.E. McKelvey illustrates part of the problem (1973):

> ...in attaining our high level of living in the United States, we have used more minerals and mineral fuels during the last 30 years than all the people of the world used previously. This enormous consumption will have to be doubled just to meet the needs of the people now living in the United States through the remainder of our lifetimes, to say nothing about the needs of succeeding generations, or the increased consumption that will take place in the lesser developed countries if they are to attain a similar level of living.

And further,

> If resource adequacy cannot be assured into the far-distant future, a major reorientation of our philosophy, goals, and way of life will be necessary. And if we do need to revert to a low resource consuming economy, we will have to begin the process as quickly as possible in order to avoid chaos and catastrophe.

If we include under "resource adequacy" the social, economic, and technological systems which convert raw resources into usable products and services, continued growth without regard for long-term dangers becomes a gamble. The Colstrip project would add to the growth of the size and complexity of the supersystem which some (Meadows et al. 1972) feel will ultimately fall. If the prediction is true, all social, economic, and environmental impacts, except as they contribute to the demise of the system, become minuscule.

7.4. Public Involvement

A public involvement program was initiated by the EPD in June of 1974, for the purpose of informing the public on the nature of the Colstrip proposal and the role of the division's study, and to record and analyze public comment about them.

The program was begun to answer a growing demand by the public for a voice in governmental actions, as well as to aid the division in assessing public concerns, in gaining new information from members of the public and in responding to public values to generate the best available solution from every point-of-view (For a detailed description of the public involvement program, see Section 12.4., Volume 3B).

7.4.1. Special Need for Public Comment on Transmission Lines Study

In the event that Colstrip Units 3 and 4 are approved, it seems clear that the transmission lines would be constructed. A decision to deny construction of the transmission lines would be a de facto decision to deny construction of the power plants. However, in the event that the generating units are approved, there is a need for public comment on the construction of the transmission lines.

Although there are a number of variables such as construction practices, the two most significant would be line design and corridor selection. The EPD intends to take local values and concerns into account when generating an optimum corridor, for science can only predict the impacts transmission line characteristics would have on separate environmental elements (see Section 6.3., "Impacts of Alternate Corridors"). To determine whether the impacts are acceptable requires comment from the public.

Trade-off situations often arise in corridor selection, in which one environmental value must be placed above another. For example, it may become necessary to evaluate visual impact along a highway against the impact of locating transmission lines in a roadless area. Many of these trade-off situations may be encountered, and they all require public comment if proper decisions are to be made.

Finally, public comment helps the division identify local concerns of which it may have been unaware. Examples of these are local private airfields, waterfowl habitat, and isolated scenic area of local values, a local historical site, etc.

7.4.2. Public Comment on the Draft EIS

A public comment period will be extended for at least 45 days following publication of this impact statement. Public comment will be solicited and accepted under a variety of methods, including verbal and written comment at public meetings, telephone calls, letters, postcards, petitions, etc.

A series of eighteen public meetings will be conducted in selected communities throughout the study area from November 25, 1974 to January 9, 1975. The communities will be, in chronological order: Plains, Ovando, Anaconda, Butte, Helena, Great Falls, Bozeman, Big Timber, Harlowton, Townsend, Custer, Hardin, Forsyth, Miles City, Billings, Polson, St. Ignatius and Missoula.

The exact times and locations of each meeting will be announced by the statewide media. A complete meeting schedule can be obtained by writing to EPD. In addition, meetings with special groups are possible by special arrangement.

All public comment received by EPD will be carefully analyzed, tabulated, and recorded. The results of all public comment will be included in the final EIS, and will be reported to the Board of Natural Resources and Conservation for its consideration in making a final decision on the application.

GLOSSARY

ASSOCIATION

In Clement's sense, a climatic climax unit that includes all of the successional stages preceding or associated with it. Plant association and animal association emphasize populations of plants and animals, respectively, within an area.

BIOMASS

Living weight; the total quantity per unit of space at a given time of living organisms of one or more species (species biomass) or at all the species in a community (community biomass). Cf. yield, productivity, standing crop.

BROADBAND

Communication channel having a bandwidth greater than a voice-grade channel, and therefore capable of higher-speed data transmission.

CAPACITIVE LOSS

The loss of power, mainly in the form of heat, due to capacitive reactance.

CAPACITIVE REACTANCE (X_C)

The characteristic of capacitors of opposing the flow of alternating current. Measured in ohms.

CAPACITORS (C)

Two conducting materials separated by insulating material, with the capability of storing electrical energy for a period of time.

CIRCUIT BREAKER

A device used to close or open an electrical circuit, especially one carrying high current and high voltage.

CLIMAX
A community capable of self-perpetuation under the prevailing climatic and edaphic conditions; the terminal stage of a sere under the prevailing conditions.

COMMERCIAL FOREST LAND
Forest land which is (a) producing, or physically capable of producing, usable crops of wood (usually sawtimber), (b) economically available now or prospectively, and (c) not withdrawn from timber utilization.

CONDENSERS
Same as capacitors

CONVERTERS
The set of electrical equipment which can convert A.C. electricity into D.C. and vice versa. The set includes rectifiers and inverters.

CURRENT
A movement of electrons due to EMF between two points (e.g. two ends of a wire) when a conducting path is provided. These electrons are part of the atoms which compose the conductor or any other matter. Measured in amperes.

DBH
Diameter breast height. On standing trees, a standard height from ground level for recording diameter, girth, or basal area. In the United States, this standard height is 4 ft. 6 in. (1.37m).

DECIBEL (db)
A unit for measuring the relative strength of a signal parameter such as power, voltage, etc. The number of decibels is ten times logarithm (base 10) of the ratio of the measured quantity to the reference level. The reference level, such as 1 milliwatt for power ratio and μv/m or mv/m for voltage; must always be indicated.

DIELECTRIC LOSS
Power loss resulting from dielectric strength.

DIELECTRIC STRENGTH

When there is an EMF between two conductors that are separated by an insulating material, there are electrical forces exerted upon the electrons in the atoms of the insulating material which tend to pull the electrons out of the atoms. This pull is called dielectric strength.

ECOSYSTEM

A community including all of its component organisms, together with the abiotic environment, forming an interacting system.

ECOTONE

A transition line or zone between two vegetation communities which has the characteristics of both kinds of neighboring vegetation as well as characteristics of it's own.

ELECTROMAGNETIC FIELD

The region around a conductor carrying A.C. current, which can exert a force on magnetic material or material carrying A.C. current if placed in proximity.

EMF (ELECTROMAGNETIC FORCE)

The force or pressure, measured in volts, which makes or tends to make electrons move.

EUTROPHICATION

The normally slow aging process by which a lake evolves into a bog or marsh and untimately assumes a completely terrestrial state and disappears. During eutrophication the lake becomes so rich in nutritive components, especially nitrogen and phosphorus, that alge and other microscopic plant life become superabundant, thereby "choking" the lake, and causing it eventually to dry up. Eutrophication may be accelerated by many human activities.

FAULT

A fracture or zone of fractures in the earth along which movement has occurred.

FOREST LAND

Land which (a) is stocked on at least 10 percent of its surface by trees of any size, and capable of producing timber or other wood products, or of exerting an influence on the climate or on the water regime; or (b) has had the trees described in (a) removed to less than 10 percent stocking, and which has not been developed for other uses.

GAUSSIAN NOISE

See white noise.

GRASSLAND

Any land on which grasses dominate. Also, land originally dominated by grasses.

GROUP

Two or more geologic formations considered as a unit.

HABITAT TYPE

Collective term for those areas that support or can support the plant association, or did support it prior to its destruction or modification by fire, flood, grazing, logging. It is the physical environment of a particular association.

IMPEDANCE

The total opposition of a conductor to the passage of an electric current through it, caused by the combined effects of the characteristics of the circuit resistance, inductance and capacitance.

INCREASER

Plant species, of the original vegetation, that increase in relative amount, at least for a time, when the community is subjected to overuse.

INDUCTANCE (L)

The property of a circuit (or conductor) that causes a voltage to be induced in the circuit (or conductor) by a change of current. Measured in henries.

INDUCTIVE LOSS

The loss of power, mainly in the form of heat, due to inductive reactance.

INDUCTIVE REACTANCE (X_L)

The characteristic of inductors of opposing the flow of alternating current. Measured in ohms.

INVADER

Plant species that are absent in undisturbed portions of the original vegetation, and will invade under disturbance or confined overuse.

INVERTER

The electrical device used to convert direct current into alternating current.

MACROSCALE

Lengths greater than fifty kilometers and areas on the order of 1000 square kilometers or greater.

MERCHANTABLE

(Said of trees, crops, or stands) of a size, quality, and condition suitable for marketing under given economic conditions, even if so situated as not to be immediately accessible for logging.

MESOSCALE

Lengths between one and fifty kilometers or areas on the order of 100 square kilometers

MICROSCALE

Lengths less than one kilometer or areas on the order of one square kilometer.

NITROGEN DIOXIDE (NO_2)

Produced from the combustion of coal, fuel oil, natural gas and gasoline used in power generating operations. NO_2 can cause direct damage to vegetation.

NONCOMMERCIAL FOREST

Forest land stocked by species that have no value commercially.

NOXIOUS PLANTS

Undesirable plant species that are unwholesome to the range or animal. Not to be confused with species declared noxious by certain laws.

OZONE (O_3)

An allotropic form of oxygen, containing three atoms in the molecule. It is a bluish gas, very active chemically, and a powerful oxidizing agent. It is formed when oxygen in the air is subjected to a silent electric discharge. It occurs in ordinary air in small amounts only. The photochemical reaction of hydrocarbons and nitric oxide can also produce ozone. Ozone can severely injure many forms of plant life.

PALATABILITY

The relish that an animal shows for a particular species, plant, or plant part.

PHASE

Used in A.C. terminology. When two alternating currents (or voltages) are in phase, they reach their corresponding zero, maximum, and intermediate values at exactly the same instant. If they do not they are said to be out of phase. The condition in which phase differences between electrical systems is at regular intervals and with a constant phase-angle is called polyphase. The alternating current used normally is three phase.

PHOTOSYNTHESIS

The synthesis of chemical compounds effected with the aid of radiant energy, especially light. Usually the formation of carbohydrates in the chlorophyll-containing tissues of plants exposed to light.

POISONOUS PLANTS

Plants containing or producing substances that, consumed by animals, result in sickness, death, or deviation from normal state of health.

POLE SIZE TREE
A young tree with DBH of 5-9".

POWER FACTOR
The ratio of the true power (watts) to the apparent power (volt-amperes), expressed in decimal or percentage such that p.f. .8 and p.f. 80% are the same.

PRISTINE (or near pristine)
Used to describe areas on which there has been little or no grazing by domestic livestock, and which has been otherwise undisturbed. These areas show the kinds and amounts of vegetation that will develop naturally on a given soil and in a given climate, and provide criteria for determining the condition of the range.

RANGE CONDITION
The state and health of the range based on what it is naturally capable of producing.

RANGE CONDITION CLASS
One of a series of arbitrary categories used to classify range condition, usually expressed as excellent, good, fair, or poor.

RECTIFIER
A device used to convert alternating current into direct current. The mercury valve, one of the primary elements of a rectifier, can now be replaced by a new electronic device called a thyristor.

RELICT
Used to describe fragments of presently existing flora on areas with a historical record of no disturbance, where that plant community is assumed to be in near-virgin condition.

RESISTANCE
The opposition offered by the internal molecular structure of materials to the movement of electricity through them.

SAW TIMBER SIZE
Trees having DBH of 9" or greater.

SEEDLINGS AND SAPLINGS

Trees having DBH of less than 5".

SERIES COMPENSATION

The use of capacitors in series to reduce the electrical length of a transmission line.

SERE

The series of stages that follow one another in an ecological succession.

SF_6

Sulfur hexafluoride, as inert gas used to cool and insulate underground transmission cables.

SITE CLASS

A measure of the relative production capacity of a site for the crop or stand under study, based e.g. on volume or height of the maximum mean annual increment that is attained or attainable at a given age.

SITE INDEX

A particular measure of site class, based on the height of the dominant trees in a stand at an arbitrarily chosen age (see site class).

SKIN EFFECT

When an alternating current flows through a conductor, there is an inductive action whereby the current in the conductor is forced towards its surface. Therefore, current density is greater at the surface than at the center of a conductor.

STOCKING

A measure of the proportion of land area actually occupied by trees, expressed in percent of canopy closure.

STRESS INVERSION

The renewal of stress in a conductor resulting from a change in polarity.

SURGE IMPEDANCE LOADING (SIL)

For any transmission line, the line inductance (measured in units of henry, identified by the symbol L) and line capacitance (measured in units of forad, identified by the symbol C) can be combined, neglecting line resistance, to give the quantity $\sqrt{L/C}$, known as surge impedance loading.

SYNCHRONOUS OPERATION

An operation which includes two interconnected electrical systems operating at the same phase and magnitude.

SYNERGISTIC EFFECT

The activity of separate agents (such as various toxicants) acting together to produce an effect which may be greater than the sum of the effects of the individual agents. The concentration (ppm) needed to cause injury is reduced, when the toxicicants are combined, from the amount needed by one or the other alone.

TILTH

The physical condition of the soil in its relationship to plant growth, considering such factors as percentage of coarse fragments, depth of bedrock, fertility, texture, etc. Usually rated as good, fair, or poor.

TSUNAMI

Large sea wave, incorrectly called "tidal wave."

UNCONFORMITY

A surface in the earth's crust representing erosion or non-deposition.

GEOLOGIC TIME SCALE

Era	Period	Epoch	Approximate Age in Millions of Years
Cenozoic	Quaternary	Recent	.01
		Pleistocene	2
	Tertiary	Pliocene	12
		Miocene	25
		Oligocene	40
		Eocene	60
		Paleocene	70
Mesozoic	Cretaceous		135
	Jurassic		180
	Triassic		225
Paleozoic	Permian		270
	Carboniferous	Pennsylvanian	310
		Mississippian	350
	Devonian		400
	Silurian		440
	Ordovician		500
	Cambrian		600
Precambrian			to 4500

BIBLIOGRAPHY

Alden, W. C. Physiography and Glacial Geology of Eastern Montana and Adjacent Areas. U. S. Geologic Survey Professional Paper 231, 1932.

Alden, W. C. Physiography and Glacial Geology of Western Montana and Adjacent Areas. U. S. Geologic Survey Professional Paper 231, 1953.

Algermissen, S. T. "Seismic Risk Map for Conterminous United States." Presented at Fourth World Earthquake Engineering Conference. Santiago, Chile, 1969.

Allen, E. O. "Food Habits and Range Use of White-tailed Deer in the Missouri River Breaks." J. Wildl. Mgmt., 32(1)(1968), 130-141.

Anonymous. Weed Control. Subcommittee of Weeds. Washington, D. C.: National Academy of Sciences. Publication #1597, 1968.

Archibald, G. International Crane Foundation biologist. Baraboo, Wisc. Personal Communication, Feb. 1, 1974.

Ashley, Joseph M. Earth Sciences Department, Montana State University. Helena, MT. Personal Communication (Slope Gradient Distribution Map-Montana; 1:500,000 scale; 10,000 meter grids), June 1974.

Auerbach, S. I.; Nelson, D. J.; and Struxness, E. G. "Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1972." Oak Ridge, Tenn.: Oak Ridge National Laboratory, Feb. 1973.

Ausland, M. Bonneville Power Administration technician. Hot Springs, MT. Personal Communication, Feb. 5, 1974.

Banko, W. E. "The Trumpeter Swan, its History, Habits and Population in the United States." North Am. Fauna, No. 63(1960), 214.

Barnes, Robert L. "Effects of Chronic Exposure to Ozone on Photosynthesis and Respiration of Pines." Abstract. Environmental Pollution, 3(2)(April 1972), 133-138.

Bayless, S. R. "Winter Food Habits, Range Use, and Home Range of Antelope in Montana." *J. Wildl. Mgmt.*, 33(3)(1969), 538-551.

Becker, Bruce W. *Pronghorn-Cattle Range Use and Food Habits Relationships in an Enclosed Sagebrush Control Area.* Montana Department of Fish and Game. Project No. W-105-R-7, Job No. W-4.8, 1972.

Berwick, Stephen H. "Observations on the Decline of the Rock Creek, Montana Population of Bighorn Sheep." M.S. thesis. University of Montana, 1968.

Boeker, E. Eagles research specialist. U. S. Bureau of Sport Fisheries and Wildlife. Denver, Colo. Personal Communication, Jan. 11, 1974.

Bonneville Power Administration. *Environmental Statement Fiscal Year 1975 Proposed Program.* U. S. Department of Interior, 1974.

Borell, A. E. "Telephone Wires Fatal to Sage Grouse." *Condor*, 41(2)(1939), 85.

Bormann, F. H.; Likens, G. E.; Fisher, D. W.; and Pierce, R. S. "Nutrient Loss Accelerated by Clear-Cutting of a Forest Ecosystem." *Science*, Vol. 159 (1968), 882-884.

Brown, C. J. D. *Fishes of Montana.* Bozeman, MT: Big Sky Books, 1971.

Brown, George W. "Predicting the Effect of Clear-Cutting on Stream Temperature." *J. Soil Water Conserv.*, 25(1)(1970), 11-13.

Brown, G. W. University of Montana graduate student. Synder, MT. Personal Communications, Jan. 28, 1974 and Feb. 6, 1974.

Brown, R. "Distribution of Plant Communities in Southeastern Montana Badlands." *The American Midland Naturalist*, Vol. 85 No. 2(April 1971), 453-477.

Buckman, H. O., and Brady, N. C. *Nature and Properties of Soils.* 7th ed. New York: MacMillan Co., 1969.

Bureau of Land Management. "Areas of Administrative Responsibility of Federal Lands, State of Montana." Scale 1:500,000, 1967.

Bureau of Land Management. Middle Yellowstone River Area Classification of Public Domain. Washington, D. C.: Government Printing Office, 1969.

Bureau of Land Management. Musselshell River Area Classification of Public Domain. Washington D. C.: Government Printing Office, 1971.

Caprio, J. M. "Average Length of Freeze Free Season." Folder No. 83. Cooperative Extension Service. Montana State College. Bozeman, March 1965.

Chrest, H. "White-tailed Ptarmigan." pp. 181-183. In Game Management in Montana. Edited by Mussehl and Howell. Helena, MT: Montana Fish and Game Department, 1971.

Ciesla, W. Missoula, MT. Personal Communication, Aug. 1974.

Coffman, J. L. and vonHake, C. A. Earthquake History of the United States (through 1970). U. S. Department of Commerce. National Oceanic and Atmospheric Administration, 1973.

Cohen, J. M., and Pinkerton, C. Widespread Translocation of Pesticides by Air Transport and Rain-out. Edited by A. A. Rosen and H. F. Kraybill. Presented at In-organic Pesticides in the Environment, a Symposium of the American Chemical Society, Atlantic City, N. J., Sept. 13-15, 1965.

Cole, G. F. The Pronghorn Antelope - Its Range Use and Food Habits in Central Montana with Special Reference to Alfalfa. Montana Fish and Game and Montana Agriculture Experiment Station Tech. Bull. No. 516, 1956.

Compton, H. O. Upland Game Bird Survey and Inventory--Region Five. Job Prog. Report Project W-130-R-4, Job II-5, 1973.

Comsa, R. P., and Rene, J. G. "Air Model for the Study of Electrostatic Induction by Transmission Lines." IEEE Trans. Power Apparatus and Systems, Vol. PAS - 87 (April 1968a), 1002-1010.

Comsa, R. P., and Rene, J. G. "Computer Analysis of Electrostatically Induced Currents on Finite Objects by EHV Transmission Lines." IEEE Trans. Power Apparatus and Systems, Vol. PAS - 87 (April 1968b), 997-1002.

Coop, K. J. Biologist. Montana Department of Fish and Game. Harlowtown, MT. Personal Communication, 1974.

Cooper. The Interagency Forage, Conservation and Wildlife Handbook. Interagency Forage, Conservation and Wildlife Handbook Coordinating Committee, 1973.

Cordone, A. J., and Kelley, D. W. "The Influences of Inorganic Sediment on the Aquatic Life of Streams." California Fish and Game, 47(2)(1961),180-223.

Cornwell, G. A., and Hochbaum, H. A. "Collisions with Wires--A Source of Anatid Mortality." Wilson Bull., 83(3)(1971), 305-306.

Covey, F., and Schallenberger, A. "Bighorn Sheep." pp. 97-105. In Game Management in Montana. Edited by Mussehl and Howell. Helena, MT: Montana Fish and Game Department, 1971.

Craighead, John J., and Craighead, F. C., Jr. "Grizzly Bear - Mans Relationships in Yellowstone National Park." Bio. Science, 21(1971), 845-857.

Craighead, John J.; Varney, J. R.; and Craighead, F. C., Jr. "A Population Analysis of the Yellowstone Grizzly Bears." Bulletin No. 4. Montana Forestry and Conservation Experiment Station. Missoula, MT, 1974.

Crawford, J. E., and Dunkeson, L. A. "Powerline Standards to Reduce Raptor Losses on the National Resource Lands." Unpublished report from U. S. Bureau of Land Management and U. S. Bureau of Sport Fisheries and Wildlife. Washington, D. C., 1973.

Critical Path Diagram - Construction of Colstrip - Broadview 230KV Double Circuit Line. Montana Power Company Drawing No. 1635-C, April 30, 1974.

Cross, James. Biologist. Montana Department of Fish and Game. Kalispell, MT. Personal Communication, 1974.

Darley, E. F., and Middleton, J. T. Annual Review of Phytopathology, IV (1966), 103-108.

Denbrock, Frank A. "The Changing Energy Business and its Effect on Energy Transport Systems." Presentation to Members of Federal Power Commission. Washington, D. C., January 26, 1972.

Department of Natural Resources and Conservation. Soil Group Workshop. Natural Elements List--Soils. Helena, MT, Jan. 15, 1974.

Dickinson, L. W. "Utilities and Birds." Audubon Mag., 59(2)(1957), 54-55, and 86-87.

Domrose, Robert. Biologist. Montana Department of Fish and Game. Kalispell, MT. Personal Communication, 1974.

Donahue, John J., Jr., and Ashley, Joseph M. "Impacts of Induced Rainfall on the Great Plains of Montana; Surface Hydrology and Geomorphology in the Great Plains of Montana." Research Report 42, Section 7-Hydrology. Montana Agricultural Experiment Station. Montana State University, Bozeman, 1973.

Dubos, René. Reason Awake: Science for Man. Columbia University Press, 1970.

Dubos, René. So Human an Animal. New York: Charles Scribner's Sons, 1968.

Dyksterhuis, E. J. "The Savannah Concept and its Use." Ecology, Vol. 58 No. 3 (1957), 435-442.

Ebert, P. Big game staff biologist. Oregon Fish and Game Comm. Portland, Oregon. Personal Communication, March 14, 1974.

Egler, F. E. "Our Disregarded Rights-of-Way--Ten Million Unused Wildlife Acres." Trans. N. Amer. Wildl. Conf., 18, (1953), 147-158.

Egler, F. E. "Rights-of-Way and Wildlife Habitat: A Progress Report." Trans. N. Amer. Wildl. Conf., 22 (1957), 133-144.

Ellis, D. H.; Smith, D. G.; and Murphy, J. R. "Studies on Raptor Mortality in Western Utah." Great Basin Nat., 29(3)(1969), 165-167.

Eng. R. Professor. Montana State University. Bozeman, Feb. 1, 1974.

Environmental Protection Agency, Air Pollution Control Office. Air Quality Criteria for Nitrogen Oxides. Washington, D. C.: Government Printing Office, 1971b.

Environmental Protection Agency. Effects of Noise on Wildlife and Other Animals. NTID 300.5. Washington, D. C.: Government Printing Office, 1971a.

Erickson, Glenn L. Biologist, Montana Department of Fish and Game. White Sulphur Springs. Personal Communication, 1974.

Erickson, Glenn L. The Ecology of Rocky Mountain Bighorn Sheep in the Sun River Area of Montana With Special Reference to Summer Food Habits and Range Movements. Montana Department of Fish and Game. Project No. W-120-R-2 and R-3, Job No. BG-9.01, 1972.

Federal Power Commission's Advisory Committee on Underground Transmission. "Underground Power Transmission." Report to the Federal Power Commission, April 1966.

Feist, Frank. Biologist, Montana Department of Fish and Game. Great Falls, 1974.

Fenneman, N. M. Physiography of Western United States. New York: McGraw-Hill Book Co., Inc., 1931.

Fern, W. J., and Brabets, R. I. "Field Investigation of Ozone Adjacent to High Voltage Transmission Lines." IEEE Transactions Paper T 74 057-6, 1974.

Fliger, R. Regional Coordinator, Montana Department of Fish and Game. Billings. Personal Communication, Feb. 13, 1974.

Florez, Arturo; McDonough, W. T.; and Balls, L. D. "Western Coneflower - A Noxious Species." Journal of Range Management, Vol. 25 No. 5(1972), 403-404.

Fog, A. J. "Om andefugle contra elledninger." (English Summary). Flora and Fauna, 76(4)(1970), 141-144.

Forest Sub-Committee, Montana Rural Area Development Committee. Opportunities for Developing Montana's Forest Resources. Cooperative Extension Service. Montana State University, Bozeman, 1971.

Foss, A., and Rognrud, M. "Rocky Mountain Goat." pp. 107-113. In Game Management in Montana. Edited by Mussehl and Howell. Helena, MT: Montana Fish and Game Department, 1971.

Fraser, G. D. "Intensity, Magnitude, and Ground Breakage." In The Hebgen Lake, Montana Earthquake of August 17, 1959. U. S. Geologic Survey Professional Paper 435, 1964.

Frederiksen, R. L. Erosion and Sedimentation Following Road Construction and Timber Harvest on Unstable Soils in Three Small Western Oregon Watersheds. U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest Range Experiment Station. Research Paper PNW-104, 1970.

Frydman, H.; Levy, A.; and Miller, S. E. "Oxidant Measurements in the Vicinity of Energized 765 KV Lines." IEEE Transactions Paper T 72 551-0, May 10, 1972.

Gordon, F. A., and Coop, K. J. Big Game Survey and Inventory--Region Five. Job Prog. Report Project W-130-R-4, Job I-5, 1973.

Gunther, G. "On the Reluctance of Gulls to Fly Under Objects." Auk, 73(1)(1956), 131-132.

Gustafson, Neil C. Recent Trends/Future Prospects--A Look at Upper Midwest Population Changes. Upper Midwest Council. Minneapolis, Minn., 1973.

Harrison, J. "Heavy Mortality of Mute Swans from Electrocution." Annual Report the Waterfowl Trust - 1961-62, 14 (1963), 164.

Harvard, Max Ray. "The Impact of Ozone on Understory Plants of the Aspen Zone." Abstract of Ph.D. thesis. Utah University. Ann Arbor, Mich: Microfilms Inc., Aug. 1971.

Heck, W. W.; Dunning, J. A.; and Hindawi, I. J. "Interaction of Environmental Factors on the Sensitivity of Plants to Air Pollution." Journal of Air Pollution Control Association, Vol. 15 (Nov. 1965), 511-515.

Hein, R. A. "Superconductivity - Large Scale Applications." *Science*, (July 19, 1974), 215.

Hendrickson, J. R. "A Hummingbird Casualty." *Condor*, 51(2)(1949), 103.

Hewlett, J. D., and Helvey, J. D. "Effects of Forest Clearfelling on the Storm Hydrograph." *Water Res. Res.*, 6(3)(1970), 768-782.

Hiatt, R. W. *The Relation of Pheasants to Agriculture in the Yellowstone and Bighorn River Valleys of Montana*. Montana State Fish and Game Commission. Helena, 1947.

Hildebrand, Peter R. *Biology of White-Tailed Deer on Winter Ranges in the Swan Valley, Montana*. Montana Department of Fish and Game. Project No. W-120-R-2, Job No. BG-5.01, 1971.

Hill, A. C.; Heggestad, H. E.; and Lenzon, S. N. "Ozone." *Recognition of Air Pollution Injury to Vegetation*. Agricultural Committee. Information Report No. 1, TR-7, Pittsburg, PA: Air Pollution Control Association, 1970.

Hindawi, I. J. *Air Pollution Injury to Vegetation*. U. S. Department of Health, Education and Welfare. Washington D. C.: U. S. Government Printing Office, 1970.

Hoaglin, E. D. "Bird Nest Problem: A Possible Solution." Unpublished report to Bonneville Power Administration.

Hoffman, R. S.; Wright, P. L.; and Newby, F. E. "The Distribution of Some Mammals in Montana. I. Mammals Other Than Bats." *Journal of Mammals*, 50(1969), 579-604.

Holdorf, H. D. Lewis and Clark National Forest Soil Scientist. Helena, MT. Personal Communication, May 1974.

Hope, C. B. Rancher. South of Bighorn, MT. Personal Communication, 1974.

Hornbeck, J. W.; Pierce, R. S.; and Federer, C. A. "Streamflow Changes after Forest Clearing in New England." *Water Res. Res.*, 6(4)(1970), 1124-1131.

Howell, B. F. Introduction to Geophysics. McGraw-Hill Book Co. Inc., 1959.

Hunt, R. D. Wisconsin Department of Natural Resources. Personal Communication, May-June 1974.

Institute of Electrical & Electronic Standard Dictionary of Electrical and Electronics Terms. Wiley Interscience, 1972.

Jaeger, J., and Banfield, W. "Response of Eastern White Pine to Prolonged Exposure to Atmospheric Levels of Ozone, Sulphur Dioxide, or Mixtures of these Pollutants." Pathology. Abstract 60(1970), 575.

Jaffe, L. S. "The Biological Effects of Ozone on Man and Animals." Amer. Indus. Hygiene Assoc. J., 28(3)(1967), 267-277.

Janson, Reuel. Big Game Survey and Inventory. Montana Department of Fish and Game. Project No. W-130-R-4, Job No. I-2, 1973a.

Janson, Reuel. Big Game Survey and Inventory. Montana Department of Fish and Game. Project No. W-130-R-4, Job No. II-2, 1973b.

Johnston, D. W., and Haines, T. P. "Analysis of Bird Mortality in October, 1954." Auk, 74(4)(1957), 447-458.

Jonkel, C. J., and Cowan, I. M. "The Black Bear in the Spruce - Fir Forest." Wildlife Monograph No. 27, 1971.

Kaschke, Marvin R. Refuge Manager, National Bison Range. Moiese, Montana. Personal Communication, 1974.

Keeton, W. T. "Orientation by Pigeons: Is the Sun Necessary?" Science, 165(3896)(1969), 922-928.

Kemper, C. A. "A Tower for TV: 30,000 Dead Birds." Audubon, 66(2)(1964) 86-90.

Kitchings, J. T.; Shugart, H. H., and Story, J. D. Environmental Impacts Associated with Electric Transmission Lines. Pub. #591. Environmental Sciences Division, Oak Ridge National Laboratory. Oak Ridge, Tenn., March 1974.

Klein, D. R. "Reaction of Reindeer to Obstructions and Disturbances." *Science*, 173(3995)(1971), 393-398.

Knight, R. R. *Elk Population Trends, Food Habits and Range Relationships in the Sun River Area.* Montana Department of Fish and Game, Project No. W-98-R-6 &7. Job No. I-4, 1967.

Knockle, K. G. "The Ecology of the Rattlesnake Creek, Montana Mule Deer Winter Range." M.S. thesis. University of Montana, 1968.

Knowlton, F. F. "Food Habits, Movements and Populations of Moose in the Gravelly Mountains, Montana." *Jour. Wildl. Mgmt.*, 24(1)(1960), 53-57.

Kuenzi, W. D. "Tertiary Stratigraphy in the Jefferson River Basin, Montana." Ph.D. thesis. Unpublished. University of Montana, 1966.

Kyrgier, James T., and Hall, James D. Symposium of Forest Land Uses and Stream Environment. Oregon State University, Corvalis, 1971.

Lay, D. W. "How Valuable are Woodland Clearings to Birdlife?" Wilson Bull., 50(1938), 254-256.

Lentfer, J. W. "A Two-Year Study of the Rocky Mountain Goat in the Crazy Mountains, Montana." *Jour. Wildl. Mgmt.*, 19(4)(1955), 417-429.

Lockhart, B. Game Management Chief, Washington Department of Natural Resources. Seattle. Personal Communication, March 15, 1974.

Loucke, Immanuel. Bureau of Outdoor Recreation. Denver, Colorado. Personal Communication, 1974.

McCartney, R. B. "The Fulvous Tree Duck in Louisiana." M.S. thesis. Louisiana State University, 1963.

McGregor, M. D., and Williams, R. E. *Forest Insect and Disease Conditions Northern Region.* Forest Service Northern Region Report #74-1, 1973.

McKelvey, V. E. "Mineral Resource Estimates and Public Policy." In United States Mineral Resources. U. S. Geologic Survey Professional Paper 820, 1973.

Mackie, R. J. Range Ecology and Relations of Mule Deer, Elk and Cattle in the Missouri River Breaks, Montana. Wildl. Mono. No. 20, 1970.

McMannis, W. J. "Geology of the Bridger Range, Montana." Geologic Society of America Bulletin, Vol. 66(1955), 1335-1430.

Marks, P. L., and Bormann, F. H. "Revegetation Following Forest Cutting: Mechanisms for Return to Steady-State Nutrient Cycling." Science, Vol. 176(1972), 914-915.

Massachusetts Institute of Technology. Man's Impact on the Global Environment. Cambridge, Mass., and London, England: The MIT Press, 1970.

Meadows, D. H.; Meadows, D. L.; Randers, J., and Behrens, W. W. The Limits to Growth: A Report For the Club of Romes' Project on the Predicament of Mankind. New York: Universe Books, 1972.

Megahan, W. F., and Kidd, W. J. "Effects of Logging and Logging Roads on Erosion and Sediment Deposition from Steep Terrain." J. Forest, 70(3) (1972).

Mendall, H. L. The Ring-Necked Duck in the Northeast. University of Maine Studies. 2nd Ser., No. 73, 1958.

Mericle, E. Wildlife agent, Washington Department of Game. Seattle. Personal Communication, March 15, 1974.

Miller, P. R.; Parmeter, J. R.; Flick, B. H.; and Martinez, C. W., "Ozone Dosage Response of Ponderosa Pine Seedlings." Air Pollution Control Association, Vol. 19(6)(1969), 435-438.

Mitchell, J. K.; Greer, K.; and Weckwerth, R. "Furbearers." pp. 197-205. In Game Management in Montana. Helena, MT: Montana Fish and Game Department, 1971.

Montana Bureau of Mines and Geology. Directory of Mining Enterprises for 1973. Butte, MT.: Montana College of Mineral Sciences and Technology, 1974.

Montana Crop and Livestock Reporting Service. Montana Agricultural Statistics. Helena, MT, 1972.

Montana Department of Fish and Game. "Montana Fish and Game Laws." Helena, 1973.

Montana Department of Highways. Tentative Construction Program, Fiscal Years 1974-1979. Helena, MT, March 1, 1974.

Montana Historic Sites Compendum. Montana Department of Fish and Game. Helena, MT, 1974.

Montana Department of Natural Resources and Conservation, Water Resources Division. "Land Classification for Potential Irrigation Planning." Helena, MT, 1974a. (Mimeographed)

Montana Power Company. The Montana Power Company's Long Range Plan, April 1, 1974.

Montana Power Company. Revised 25 Year Long Range Plan. Transmission Requirement 1990-2010 Systems. Unpublished.

Morris, M. S. "An Ecological Basis for the Classification of Montana Grasslands (A Summary)." Montana Academy of Science, Vol. 5 and 6 (1945 and 1946), 41-44. Revised, Aug. 1954.

Morris, M. S. Natural Vegetation of Montana. Map adapted from U. S. Forest Service and other Sources. Missoula, MT.: University of Montana, 1964.

Morris, M. S. University of Montana, Missoula. Personal Communication, 1973.

Morris, Melvin and Meuchel, Joseph. The Problem of Saint Johnswort in Western Montana. Montana Forest and Conservation Experiment Station School of Forestry. University of Montana Bulletin No. 4, July 1956.

Murphy, L. M., and Brazee, R. J. "Seismological Investigations of the Hebgen Lake Earthquake." In The Hebgen Lake, Montana Earthquake of August 17, 1959. U. S. Geologic Survey Professional Paper 435, 1964.

Mussehl, T. W., and Howell, F. W., eds. Game Management in Montana. Helena, MT.: Montana Department of Fish and Game, 1971.

Mussehl, T. P.; Schladweiler, P.; and Weckwerth, R. "Forest Grouse." pp. 143-151. In Game Management in Montana. Edited by Mussehl and Howell. Helena, MT: Montana Fish and Game Department, 1971.

Nellis, Carl H. "The Mule Deer of the National Bison Range: Population Dynamics, Food Habits and Physical Condition." M. S. thesis. Montana State University, 1964.

Nelson, M. Eagle research specialist. Boise, Idaho. Personal Communication, Jan. 7, 1964.

Norwood, E. E. Geological History of Central and South-Central Montana. Bulletin of the American Assoc. of Petroleum Geologists, 1965.

Oak Ridge National Laboratory. "Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1972." Oak Ridge, Tennessee, Feb. 1973.

Packer, Paul E. "Criteria for Designing and Locating Logging Roads to Control Sediment." Forest Science, Vol. 13 No. 1(1967).

Palk, B. V., and Hanson, J. M. "San Ferinando Earthquake of February 9, 1971: Effects on Power System Operation and Facilities." Unpublished Report of the Department of Water and Power of the City of Los Angeles, 1973.

Pardee, J. T. "Late Cenozoic Block Faulting in Western Montana." Geologic Society of America Bulletin, Vol. 61(1950), 359-406.

Parsons, L. D. Big game supervisor. Washington Department of Game. Seattle. Personal Communication, March 15, 1974.

Payne, G. F. Vegetative Range Types in Montana. Bulletin #671. Department of Animal and Range Sciences. Montana Agriculture Experiment Station. Bozeman, 1973.

Perry, Eugene S. Montana in the Geologic Past. Montana Bureau of Mines and Geology Bulletin 26, 1962.

Pfister, R. D.; Kovalchik, B. C.; Arno, S. F.; and Presby, R. C. Forest Habitat Types of Montana. Intermountain Forest and Range Experiment Station and Northern Region. Missoula, MT, May 1974.

Pierce, W. G. The Rosebud Coal Field, Rosebud and Custer Counties, Montana. U. S. Geological Survey Bulletin 847-B, 1936.

Pissot, H. J., and Hanson, H. E. The Forest Resources of Western Montana. Forest Service. Resource Bulletin INT-1. Government Printing Office, 1963.

Pyke, Larry. Forester, Department of Natural Resources and Conservation, Forestry Division. Billings, MT. Personal Communication, July 31, 1974.

Reilly, W., ed. The Use of the Land: A Citizens' Policy Guide to Urban Growth. New York: Thomas Y. Crowell Co., 1973.

Roach, J. E.; Chartier, V. L.; and Dietrich, R. M. "Experimental Oxidant Production Rates for EHV Transmission Lines and Theoretical Estimates of Ozone Concentrations Near Operating Lines." Paper T73-414-0, 1973.

Robinson, G. D. Geology of the Three Forks Quadrangle, Montana. U. S. Geologic Survey Professional Paper 370, 1963.

Rohlfs, G. "Design of Recreation Grounds for Different Requirements." In Landscape and Human Life. Edited by Clifford Tandy. Amsterdam: Djambatam, 1966.

Ross, C. P., and Nelson, W. H. "Regional Seismicity and Brief History of Montana Earthquakes." In The Hebgen Lake, Montana Earthquake of August 17, 1959. U. S. Geologic Survey Professional Paper 435, 1964.

Ross, John W. Attorney, Montana Power Company. Personal Communication, Sept. 9, 1974.

Rotunno, Noreda. "The Design of Recreational Grounds for Different Requirements." In Landscape and Human Life. Edited by Clifford Tandy. Amsterdam: Djambatam, 1966.

Rudd, R. L. Pesticides and the Living Landscape. Madison, Wisc.: University of Wisconsin Press, 1964.

Rural Electric Administration Bulletin 61-10. Powerline Contacts by Eagles and Other Large Birds, 1972.

Saunders, J. K., Jr. "Food Habits and Range Use of the Rocky Mountain Goat in the Crazy Mountains, Montana." J. Wildl. Mgmt., 19(4)(1955), 429-437.

Schallenberger, A. D. "Food Habits, Range Use and Interspecific Relationships of Big-horn Sheep in the Sun River Area, Westcentral Montana." M. S. thesis. Unpublished. Montana State University, 1966.

Scherer, H. N., Jr.; Ware, B. J.; and Shih, C. H. "Gaseous Effluents Due to EHV Transmission Line Corona." IEEE Transactions Paper T72 550-2, May 22, 1972.

Scott, H. W. The Montana Earthquake of 1935. Montana Bureau of Mines and Geology. Butte, MT. Memoir No. 16, 1936.

Schumm, S. A., and Hadley, R. F. Progress in the Application of Landform Analysis in Studies of Semi-arid Erosion. U. S. Geological Survey Circular 437. Washington, D. C.: Government Printing Office, 1961.

Shah. Helena, MT. Personal Communication, July 1974b.

Shah, R. R., Principal Engineer Commonwealth Associates Inc., Jackson, Michigan. "Electromagnetic and Electrostatic Considerations in EHV Line Design, Location and Operation." Presented at the 1974 Annual Conference Southeastern Electric Exchange. Washington, D. C., April 17-19, 1974a.

Singer, F. S. "Human Energy Production as a Process in the Biosphere." In The Biosphere. (Originally in Sept. 1970 issue of Scientific American). San Francisco: W. H. Freeman and Co., 1970.

Smith, R. B., and Sbar, M. L. "Comtemporary Tectonics and Seismicity of the Western United States with Emphasis on the Intermountain Seismic Belt." Geologic Society of America Bulletin. Vol. 85 (Aug. 1974), 1205-1218.

Snyder, Allen. Carbon County Appriser's Office. Personal Communication, Oct. 1974.

Soil Survey Staff. Soil Taxonomy. Washington, D. C.: Soil Conservation Service, Oct. 1973.

Stearns, Forest. Urbanization and Environment. Edited by Thomas R. Detwyler and Melvin G. Marcus. Belmont, California: Duxbury Press, 1972.

Stewart, S. W.; Hoffman, R. B.; and Diment, W. H. "Some Aftershocks of the Hebgen Lake Earthquake." In The Hebgen Lake, Montana Earthquake August 17, 1959. U. S. Geologic Survey Professional Paper 435, 1964.

Stout, I. J. "The Nature and Pattern of Monhunting Mortality in Fledged North American Waterfowl." M. S. thesis. Unpublished. Virginia Polytech. Institute, 1967.

Sumner, J. Arlee Jr. High School teacher. Arlee, MT. Personal Communication, Jan. 28, 1974.

Tabor, R. D.; Scott, D. R.; Driver, C. H.; Erickson, C.; Bradley, W.; Schoen, J.; and Leschner, L. Wildlife Response to Right-of-Way Management. College of Forest Resources Center for Ecosystem Studies. Research Project G3-1013, 1972-1973.

Taylor, O. C. "Oxidant Air Pollutants as Phytotoxins." Presented at 57th Annual Meeting of Air Pollution Control Association. Houston, Texas, June, 1967.

Taylor, O. C.; Dugger, W. M., Jr.; Thomas, M. C.; and Thompson, C. R. "Effects of Atmospheric Oxidants of Apparent Photosynthesis of Citrus Trees." *Abstract*. Plant Physiological Supplements No. 36 Vol. XVIII, 1961.

Taylor, O. C., and Maclean, D. C. "Nitrogen Oxide and Peroxyacyl Nitrates." *Recognition of Air Pollution Injury to Vegetation*. Agricultural Committee. Information Report No. 1, TR-7, Pittsburg, PA: Air Pollution Control Association, 1970.

Taylor, W. K., and Anderson, B. H. "Nocturanal Migrants Killed at a Central Florida TV Tower; Autumns 1969-1971." *Wilson Bull*., 85(1)(1973), 42-51.

Terres, J. K. "Death in the Night." *Audubon Magazine*, 58(1)(1956), 18-20.

Thom, W. T., Jr. "Tectonic Relationships, Evolutionary History and Mechanics of Origin of the Crazy Mountain Basin, Montana." *Billings Geological Society 8th Annual Field Conference Guidebook*, 1957.

Tingey, D. T.; Reinert, R. A.; Dunning, J. A.; and Heck, W. W. "Foliar Injury Responses of Eleven Plant Species to Ozone/Sulphur Dioxide Mixtures." *Atmospheric Environment*, 7(1973), 201-208.

Treshaw, M. "Evaluation of Vegetation Injury as an Air Pollution Criterion." *Journal of Air Pollution Control Association*, XV (June 1965), 266-269.

U. S. Bureau of Sport Fisheries and Wildlife. *Raptor Electrocution Data*. Washington, D. C.: Government Printing Office, March 7, 1973b.

U. S. Bureau of Sport Fisheries and Wildlife. *Threatened Wildlife of the United States*. Research Publication 114. Washington, D. C.; U. S. Government Printing Office, 1973.

U. S. Department of Commerce. Bureau of the Census. *Numbers of Inhabitants*. Final Report PC(1)-A28 Montana. Washington, D. C.: Government Printing Office, 1970.

U. S. Department of Commerce. NOAA. "Climate of Montana." *Climatography of the United States*, No. 60-24. Washington, D. C.: Government Printing Office. Revised, March 1971.

U. S. Department of Commerce. NOAA. "Local Climatological Data, Annual Summary with Comparative Data, Billings, Montana." Asheville, N. C.: National Climatic Center, 1972a.

U. S. Department of Commerce. NOAA. "Local Climatological Data, Annual Summary with Comparative Data, Great Falls, Montana." Asheville, N. C.: National Climatic Center, 1972b.

U. S. Department of Commerce. Preliminary Census Data (Series E). Provided to the Pacific Northwest River Basin Commission by the U. S. Water Resources Council. Unpublished, 1973.

U. S. Department of Commerce. Weather Bureau. "Decennial Census of the United States Climate, Climatic Summary of the United States Supplement for 1951 through 1960, Montana." Climatography of the United States No. 86-20. Washington, D. C.: U. S. Government Printing Office, 1965.

U. S. Department of Commerce. Weather Bureau. "Local Climatological Data with Comparative Data, Butte, Montana." Ashville, N. C.: National Climatic Center, 1960.

U. S. Department of Interior. Bonneville Power Administration. Draft Environmental Statement, General Construction and Maintenance Program, Jan. 14, 1974.

U. S. Department of Interior. The National Register of Historic Places. Washington, D. C.: Government Printing Office, 1973.

U. S. Forest Service. Aerial Photographs. 1:60,000 scale, 1971, 1972.

U. S. Forest Service. Ecosystem Task Force. Ecoclass - A Method for Classifying Ecosystems. Intermountain Forest Science Laboratory. Missoula, MT. Jan. 1973.

U. S. Forest Service. Forest Service Statistical Survey. Northern Rocky Mountain Forest Experiment Station. Granite County. Report No. 13, 1942.

U. S. Forest Service. Manual of the Cavices of the Rocky Mountain and Colorado Basin, by F. J. Hermann. Agriculture Handbook No. 374. Washington, D. C.: Government Printing Office, 1970.

U. S. Forest Service. Personal Communications, Aug. 23, 1974 through Sept. 11, 1974.

U. S. Geological Survey. Army Map Service Area Maps, (1:250,000) USGS, 1954:

Wallace
Choteau
Great Falls
Lewistown
Hamilton
Butte
White Sulphur Springs
Roundup
Forsyth
Dillon
Bozeman
Billings
Hardin

U. S. Geological Survey. Geologic Map of Montana. By Clyde P. Ross, David A. Anderson, and Irving J. Witkind, USGS 1955.

U. S. Geological Survey. Reported Occurrences of Selected Minerals in Montana. By Bentley and Mowat. Washington, D. C.: USGS, 1967.

U. S. Soil Conservation Service. Average Annual Precipitation Montana. Washington, D. C.: Government Printing Office, 1974.

U. S. Soil Conservation Service. "Montana Soil and Water Conservation Needs Inventory." Bozeman, MT, 1970.

U. S. Soil Conservation Service. Soil and Vegetation Inventory of Near-Pristine Sites-Montana. By Robert L. Ross, Earl P. Murray, and June G. Haigh. Bozeman, MT, July 1973.

Wade, Nicholas, "Sahelian Drought: No Victory for Western Aid." Science, Vol. 185 No. 4147 (July 19, 1974).

Walker, E. A. "An SST is Inevitable." Centre Daily Times (SMC College, PA), March 23, 1971.

Walkinshaw, L. H. "Sandhill Cranes Killed by Flying into Power Line." Wilson Bull., 68(4)(1956), 325-326.

Watts, C. R.; Feist, Frank G.; and Schallenberger, Allen D. Big Game Survey and Inventory, Dist. 4 (Deer and Elk). Montana Department of Fish and Game. Project No. W-130-R-3, Job No. I-4, 1972.

Watts, C. R.; Feist, Frank G.; Schallenberger, Allen D.; and Erickson, Glenn L. Upland Game Bird Survey and Inventory, Dist. 4(Native). Montana Department of Fish and Game. Project No. W-130-R-4, Job No. II-4, 1973.

Weckwerth, R. "Black Bear." pp. 115-119. In Game Management in Montana. Edited by Mussehl and Howell. Helena, MT: Montana Fish and Game Department, 1971a.

Weckwerth, R. "Grizzly Bear." pp. 121-125. In Game Management in Montana. Edited by Mussehl and Howell. Helena, MT: Montana Fish and Game Department, 1971b.

Weckwerth, Richard, and Cross, Jim. Big Game Survey and Inventory. Montana Department of Fish and Game. Project No. W-130-R-4, Job No. I-1, 1973.

Weidman, R. M. "The Montana Lineament." Billings Geological Society 16th Annual Field Conference Guidebook, 1965.

Wentland, H. J. "Summer Range Habits of the Pronghorn Antelope in Central Montana with Special Referance to Proposed Sagebrush Control Study Plots." M. S. thesis. Unpublished. Montana State University, 1968.

West, H. J.; Brown, J. E.; and Kinyon, A. L. "Simulation of EHV Transmission Line Flashovers Initiated by Bird Excretion." IEEE Transaction Paper 71 TP 145-PWR, 1971.

Western Systems Coordinating Council. Reply to Federal Power Commission Docket R-362. "Reliability and Adequacy of Electric Service." Order No. 383-3, 1974.

Westinghouse Corporation. Electrical Transmission and Distribution Reference Book, 4th ed., 1964.

Westinghouse Environmental Systems. Colstrip Generation and Transmission Project, Applicant's Environmental Analysis, 1973.

Westlake, W. E., and Gunther, F. A. Occurrence and Mode of Introduction of Pesticides in the Environment. Edited by A. A. Rossen and H. F. Kraybill. Presented at In-organic Pesticides in the Environment, a Symposium of the American Chemical Society, Atlantic City, N. J., Sept. 13-15, 1965.

White, H. Oregon Cooperative Wildlife Research Unit. Portland, Oregon. Personal Communication, March 14, 1974.

Whitmore, F. C., and Durfee, R. L. Determination of Coronal Ozone Production by High Voltage Power Transmission Lines. Springfield, VA.: Versar Inc., Nov. 1973.

Wilkerson, Ronald H. Colstrip Coordinator, Kalispell District Manager. Bonneville Power Administration. Letter. May 30, 1974.

Willard, D. E., and Willard, B. J. "The Interaction Between Some Human Obstacles and Birds." M. S. thesis. University of Wisconsin. Unpublished.

Wipperman, A. H.; Martinka, R. R.; and Constan, J. K. "Smith River Drainage Inventory and Planning Investigation." Federal Aid to Fishand Wildlife Restoration Project FW-1-R-3, 1973.

Yeager, H. A. Navajo Power Project-500 KV Lines. Final Report. U. S. Department of Agriculture. Forest Service Prescott N. F., 1973.

Young, L. B. Power over People. New York, N. Y.: Oxford UniversityPress, 1973.

Zabrosky, J., and Rittenhouse, J. W. Electric Power Transmission. Chapter 4. New York: The Ronald Press, 1954.

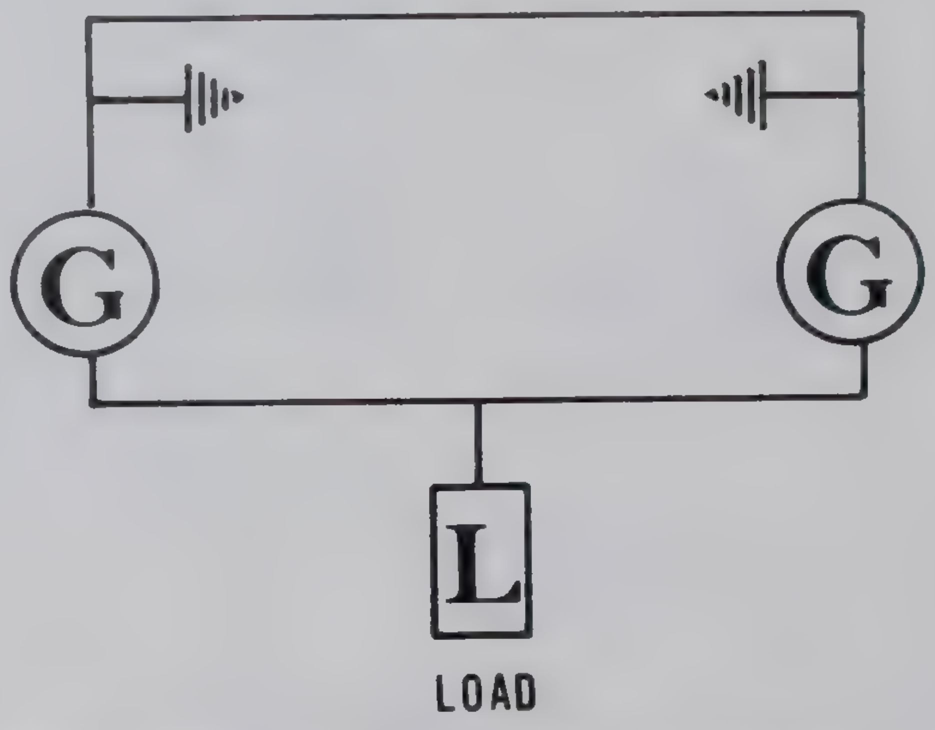
APPENDIXES

APPENDIX I: Electrical Systems

I1 Power System Stability

In order to achieve stability in an A.C. power system, synchronism-having the same phase and magnitude of frequency-must be maintained throughout the system. For example, if two A.C. generators are connected in parallel, without any external circuit connections (Figure 1), and if their internal voltages are equal in magnitude and phase, no current will flow in the circuit. The generators are said to be synchronous.

A.C. GENERATORS
IN PARALLEL
FIGURE 1

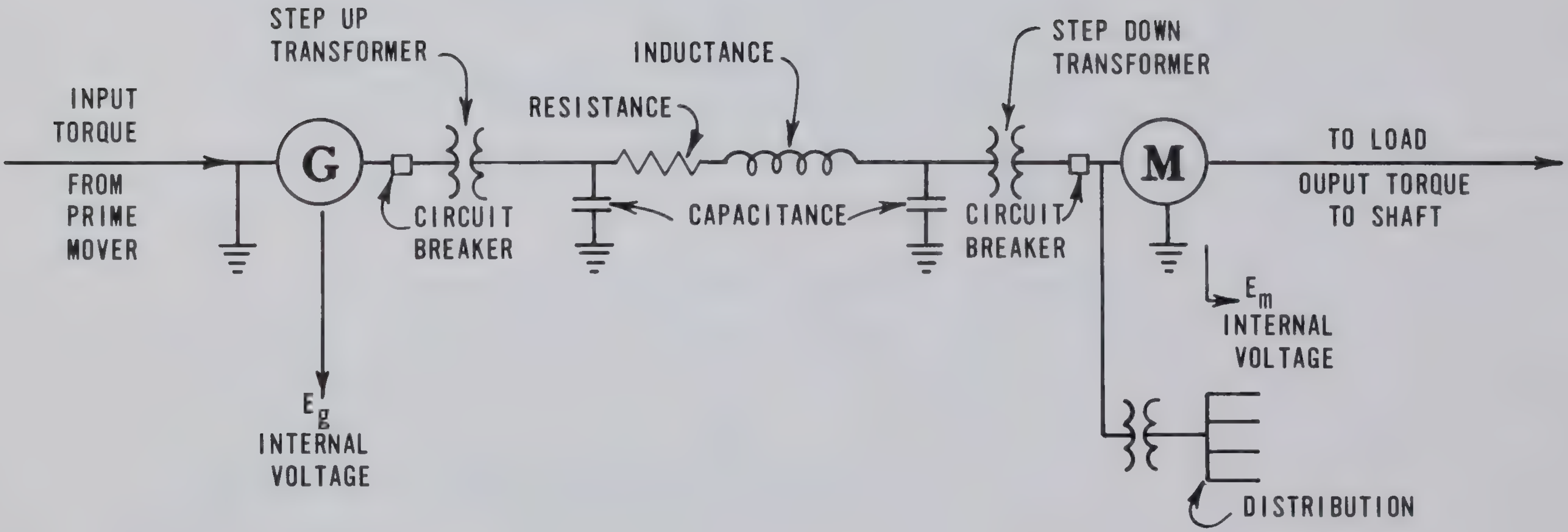


If their internal voltages are equal in magnitude, but different in phase, or vice versa, current will begin to flow in the circuit. One generator will begin to supply power to the other, which will act as a motor rather than a generator. At this point, the system has lost synchronism, and will eventually break down.

Loss of synchronism can cause damage to machinery connected to an A.C. system. When A.C. generators were driven by reciprocating steam engines, one problem that arose was the vibration of machinery connected to the system. Periodic variations in the torque applied to the generators by the steam engines (prime movers) caused periodic variations in generation, which, when transmitted to any motors connected to the system at the power delivery point, caused the motors to lose synchronism. If the natural frequency of oscillation of the motor coincided with the frequency of oscillation caused by the engines driving the generators, damage to the motors or connected machinery could result. Damper windings are effective in reducing the hazards of this vibration.

The stability problem can be illustrated using the example of a large motor connected through a transformer to a large power source. If the mechanical load on the motor is increased beyond the amount that the motor can handle with the level of electrical power it is receiving, extra power is supplied to the motor from the stored energy in the rotating generating system (flywheel) attached to the motor. If even more power is required for the motor to act on its increased mechanical load, the motor's speed decreases, with the stored energy continuing to supply part of the load. The angle between the internal voltage of the motor and the voltage of the power system increases until the electric power input to the motor is equal to the motor's mechanical power output. If this occurs smoothly before the motor ceases to operate, the system does not lose synchronism and is said to be stable.

The most common A.C. power system includes a generator connected to a motor (or many motors) by a transmission line (Figure 2).



A.C. TRANSMISSION – WITH INTERNAL VOLTAGE

FIGURE 2

Factors essential to this system are:

Mechanical:

1) Prime mover input torque and shaft load output torque.
2) Inertia of prime mover, generator, motor, and shaft load.

Electrical:

1) Internal voltage of generator and motor.
2) Reactance of the system, including generator, motor, and connecting transmission line.

Using power circle and power angle performance characteristics, power transfer in a three-phase system is:

$$P = \frac{\overline{Eg}\ \overline{Em}}{X} \quad \mathrm{Sin}\ \sigma$$

where: P = three-phase power transferred, in watts.

$\overline{Eg}$ = internal voltage of generator (line to line) in watts.

$\overline{Em}$ = internal voltage of motor (line to line), in watts.

X = reactance between internal voltages of generator and motor, including transmission lines, in ohms/phase.

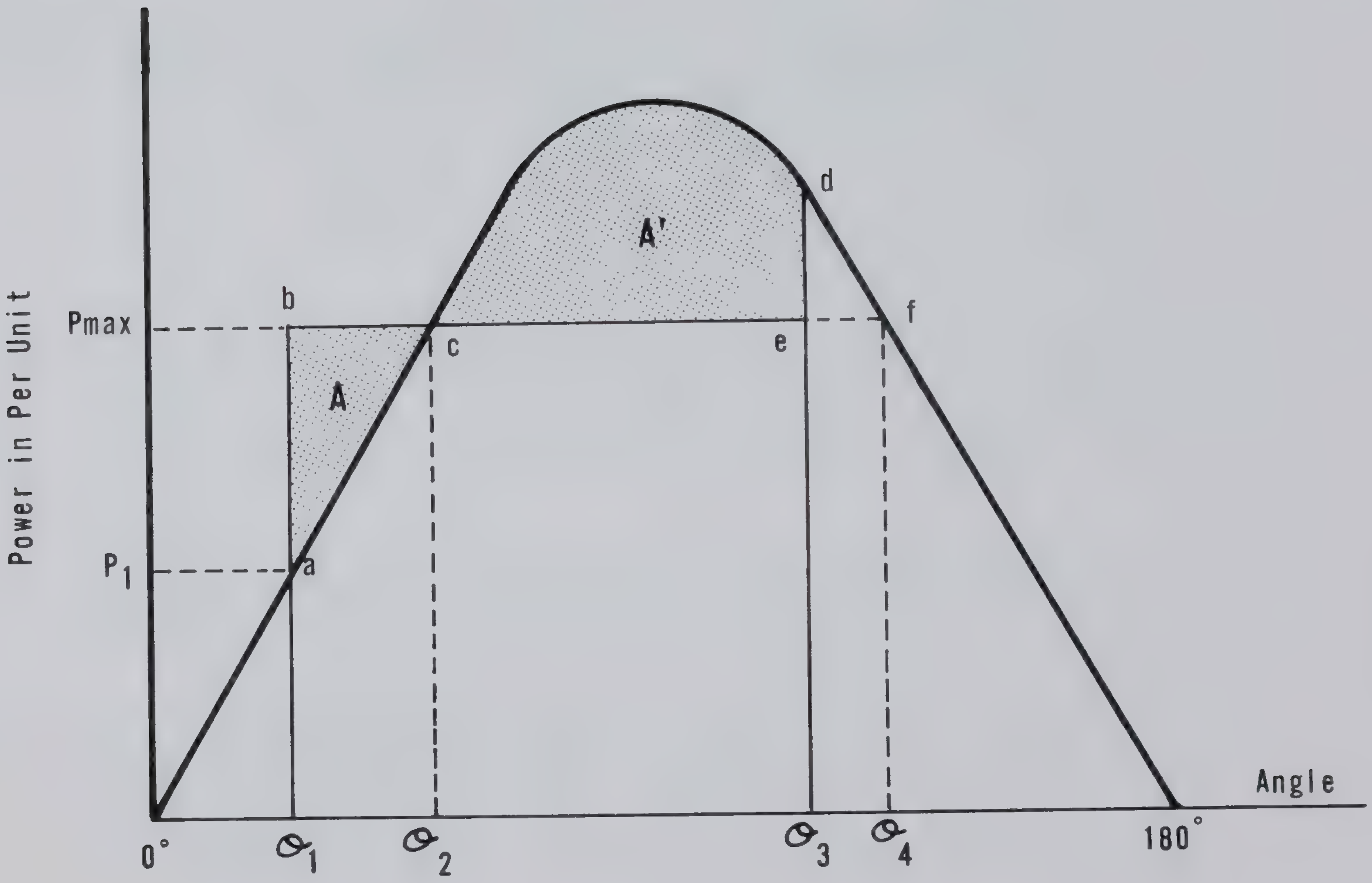
σ = angle between internal voltages of generator and motor.

Losses are ignored in the above equation, since they have no effect other than to introduce damping, for which allowances can easily be made.

The steady state stability limit can be established from the above equation. When $\sigma = 90^0$:

$$P_{max} = \frac{\overline{Eg}\ \overline{Em}}{X}$$

Transient stability limit: Transient disturbances are of three principal types: those due to load increases, those due to a switching operation (operation of circuit breakers, for example, and those due to faults. For all of these disturbances, equal-area criteria (see Figure 3) can be applied, and maximum power limits established. In the following figure, for a stable system, A must be $\geq A^1$.



EQUAL AREA CRITERIA

FIGURE 3

I2 Circuit Breakers (CB)

Because of their cost and importance to the system, the generators, transformers, and transmission lines of any power system must be protected. These elements should be isolated to prevent or limit damage during faults and overloads. This isolation is accomplished by the use of protection devices, such as circuit breakers, disconnect switches, and relays which minimize the effects of the malfunction on the rest of the power system. Generally, a power system is divided into subgroups or zones (Figure 1); each zone is protected by the devices mentioned above (Figure 2).

When high currents and voltages are involved, circuit breakers are used as protective devices. Circuit breakers, as their name implies, have the capability to interrupt an electrical circuit; when this occurs, sparks result, which must somehow be absorbed. Oil, air, or inert gas can be made to adequately absorb sparks, and each is used in one of the three types of circuit breakers commonly used: oil CB (Figures 3 and 4), air blast CB (Figure 5), and gas-filled CB.

Power systems operating at low current and voltage employ disconnect switches, which can be operated manually or automatically (Figure 6). Relays are used to signal when it is necessary to operate circuit breakers or disconnect switches (Figure 7).

Lightning arrestors (Figure 8), used to protect transformers and generators from lightning, automatically short-circuit lightning current, and provide an open circuit during normal operation.

Circuit breakers for HVDC are still in the developmental stage.

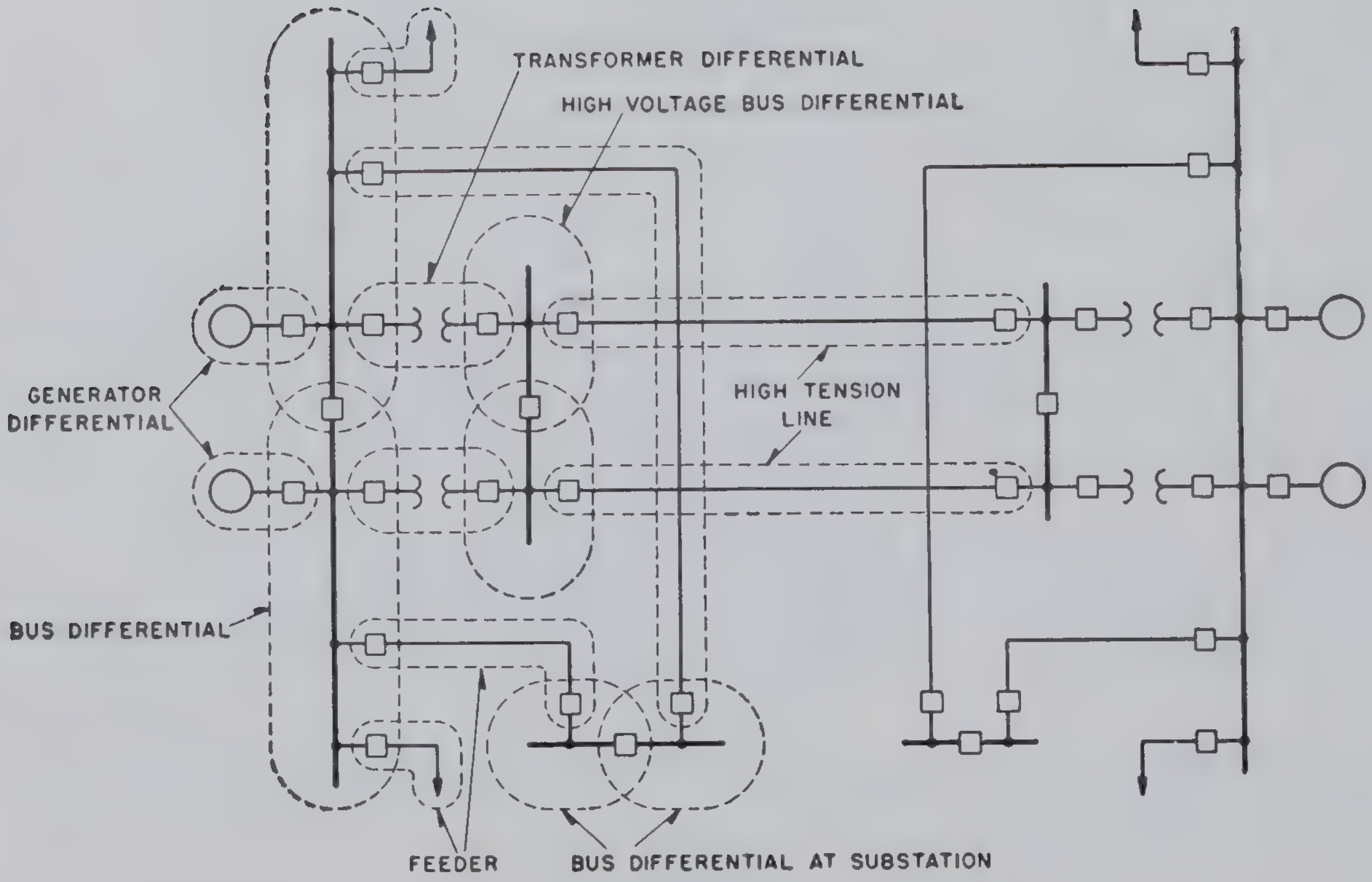


Figure 1: Power System with Protective Zones

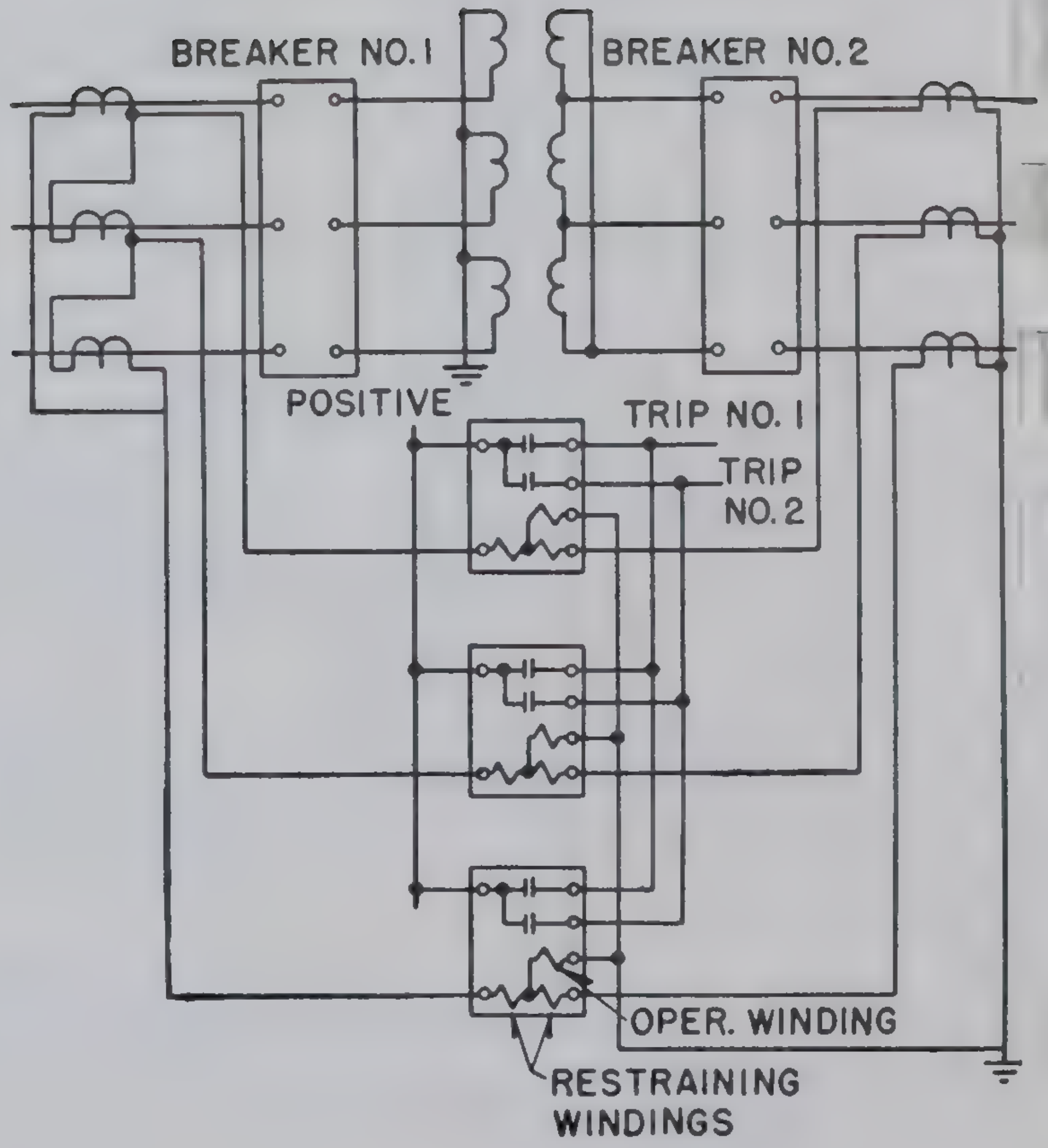


Figure 2: Circuit Breakers and Relays for Transformer Protection (Typical "Differential Protection" Device)

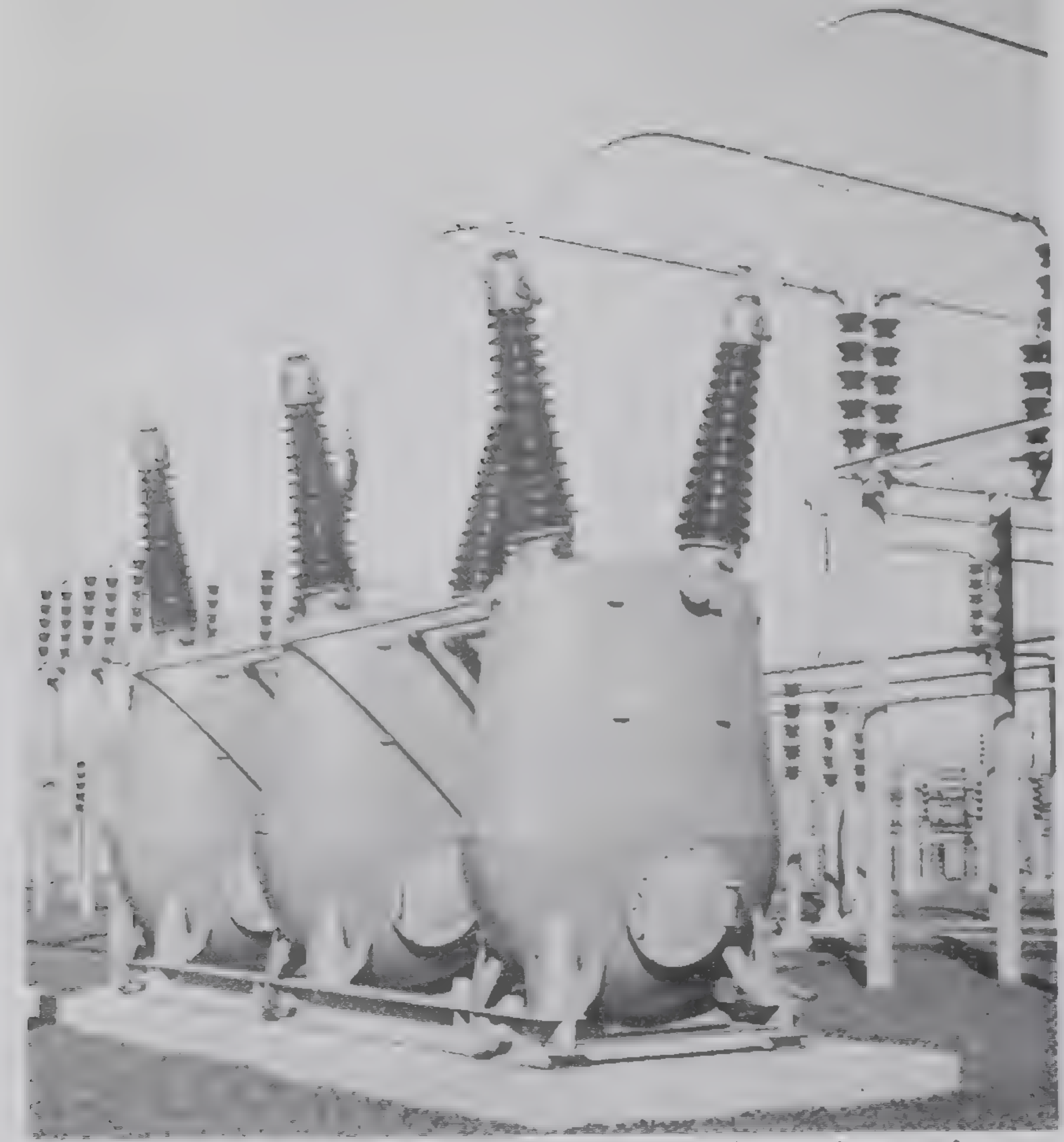
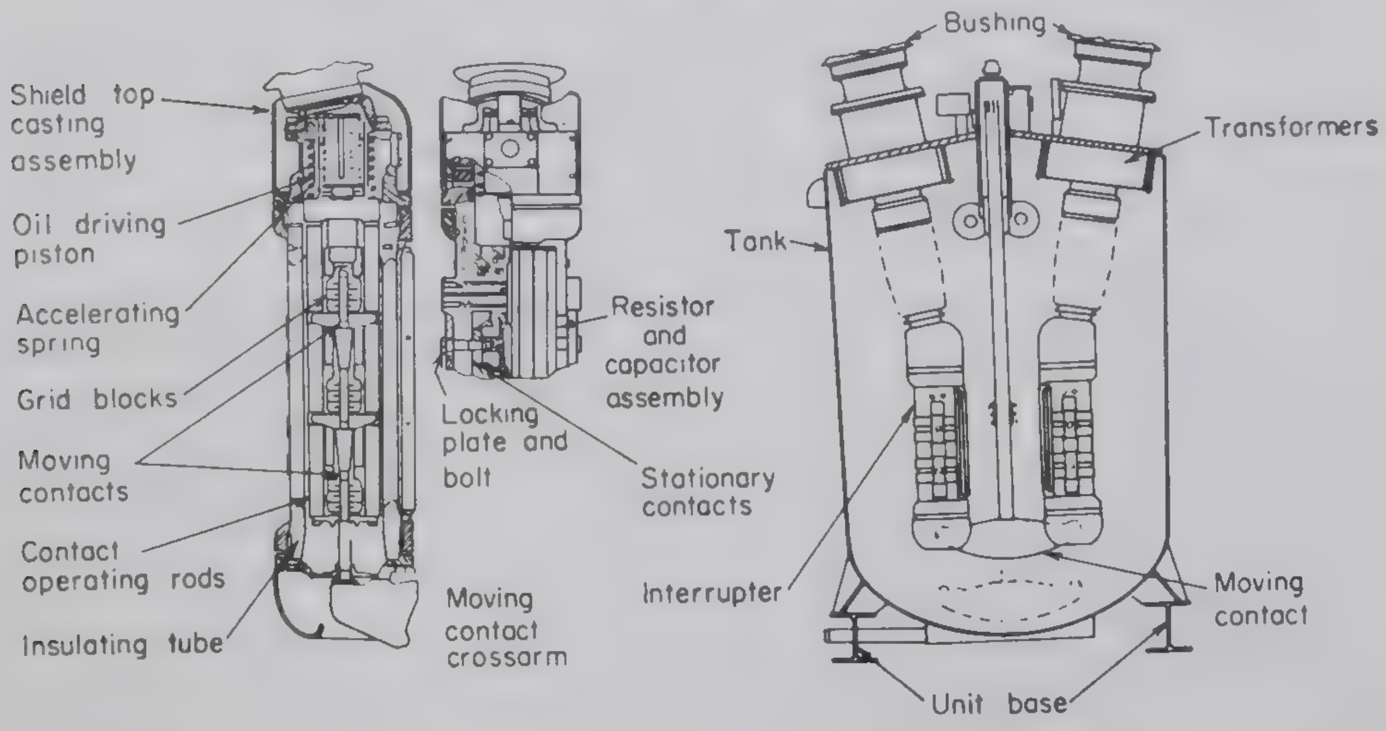


Figure 3: Oil Circuit Breakers in Substation

Figure 4: High Voltage Oil Circuit Breakers - Inside Mechanism



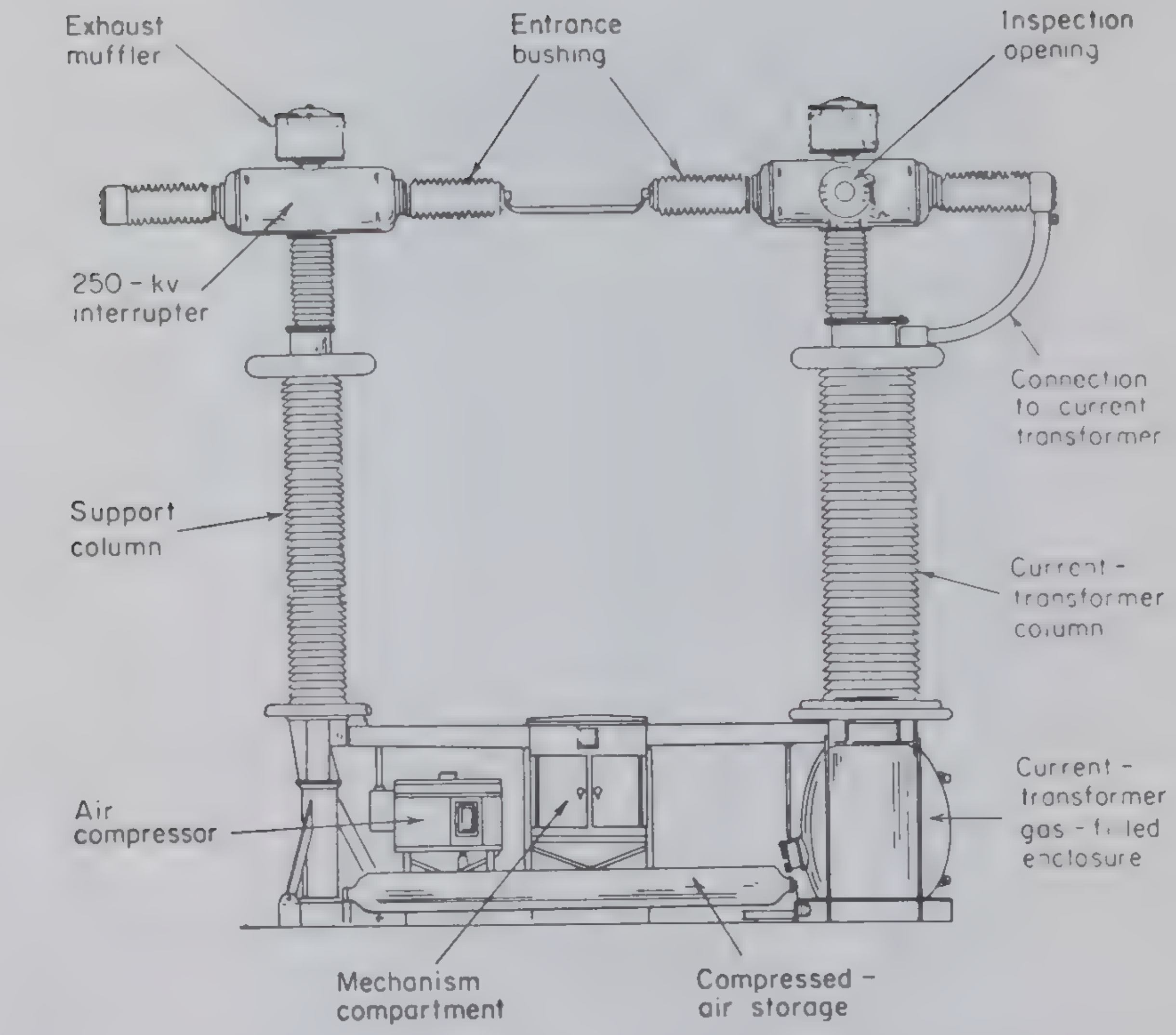
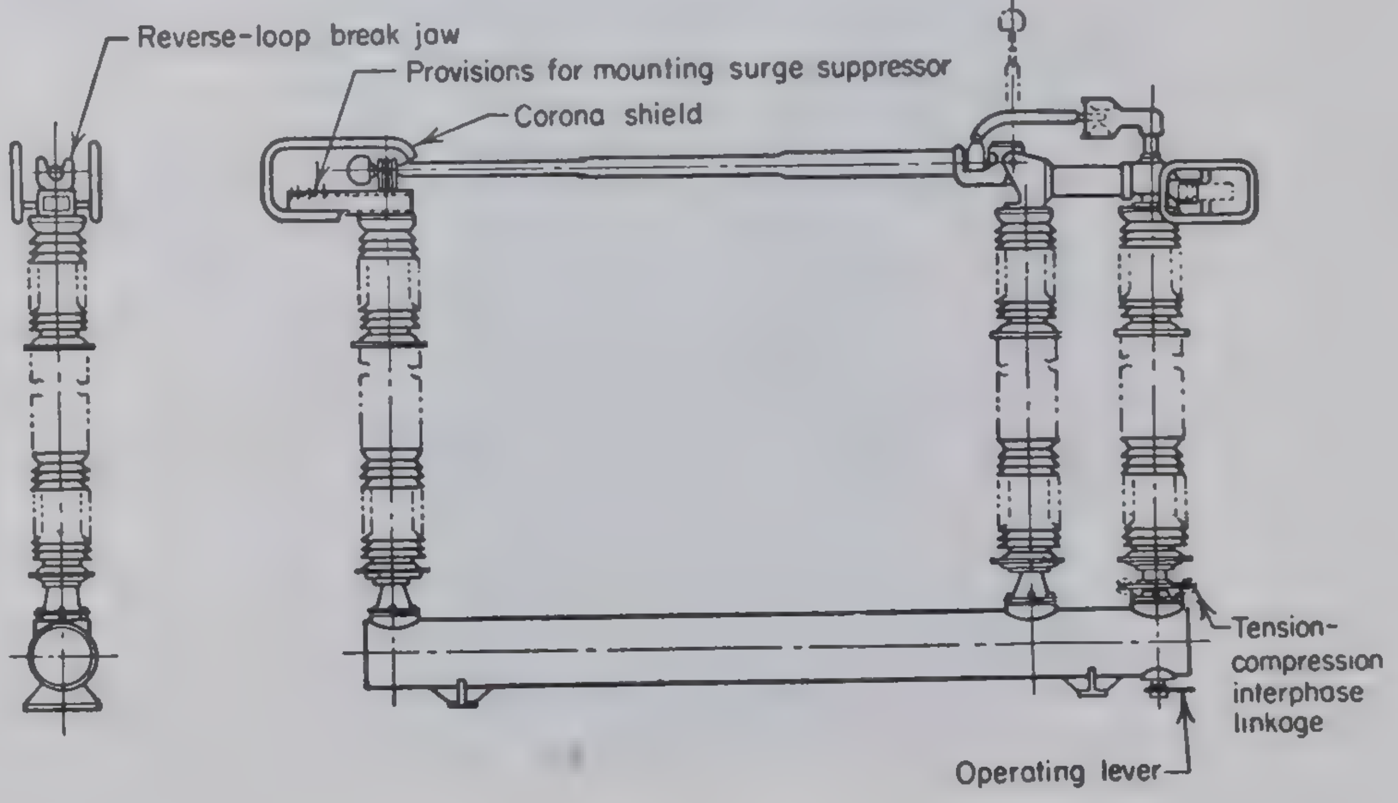


Figure 5: High Voltage Air Blast Circuit Breakers

Figure 6: Disconnect Switch


Reverse-loop break jaw
Provisions for mounting surge suppressor
Corona shield
Tension-compression interphase linkage
Operating lever

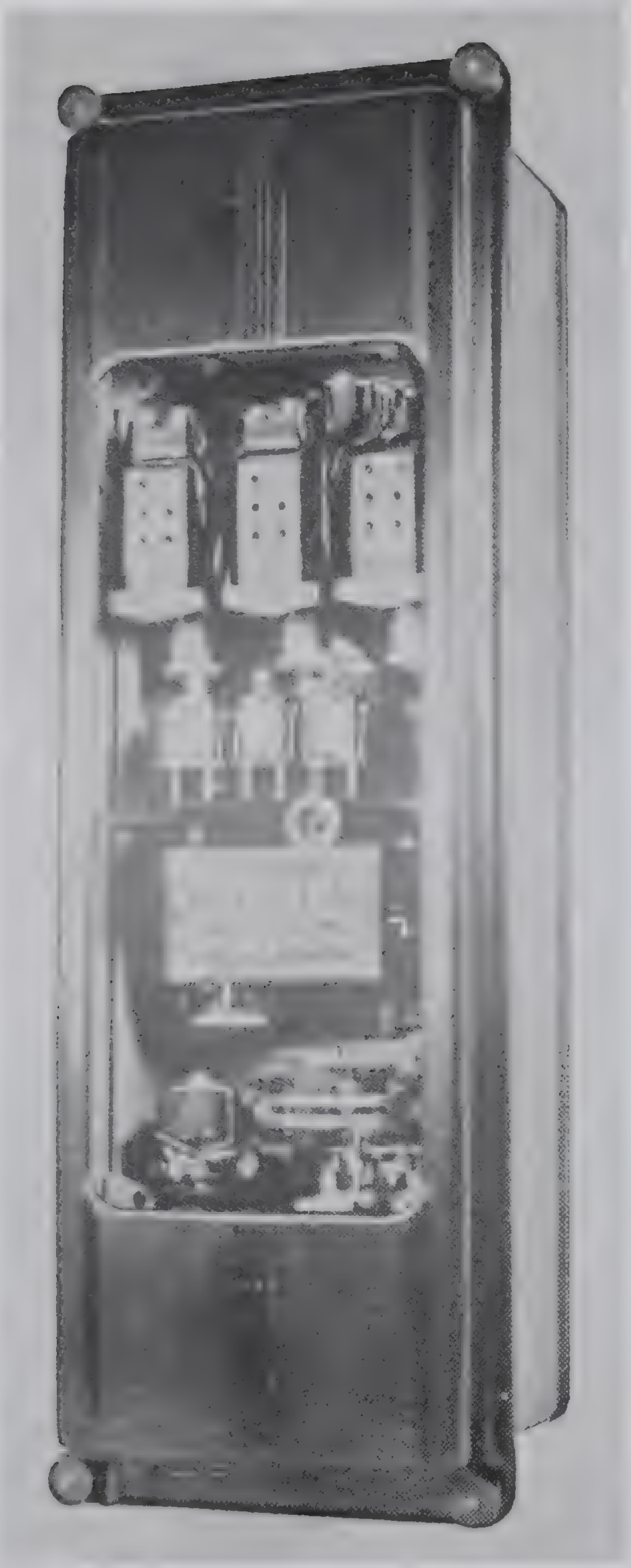
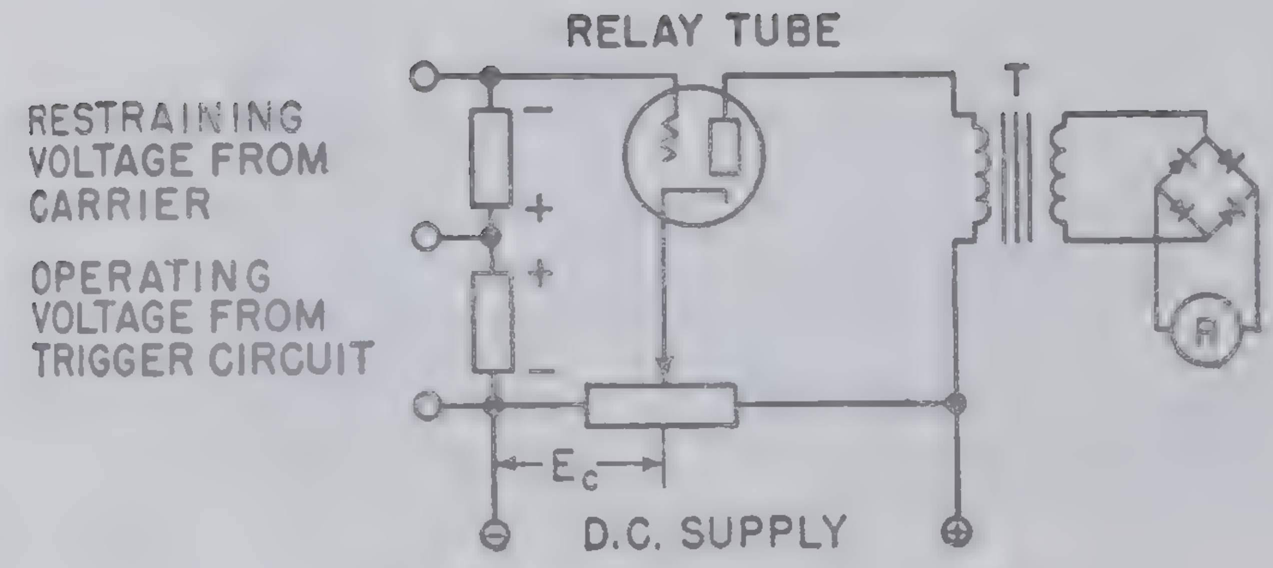
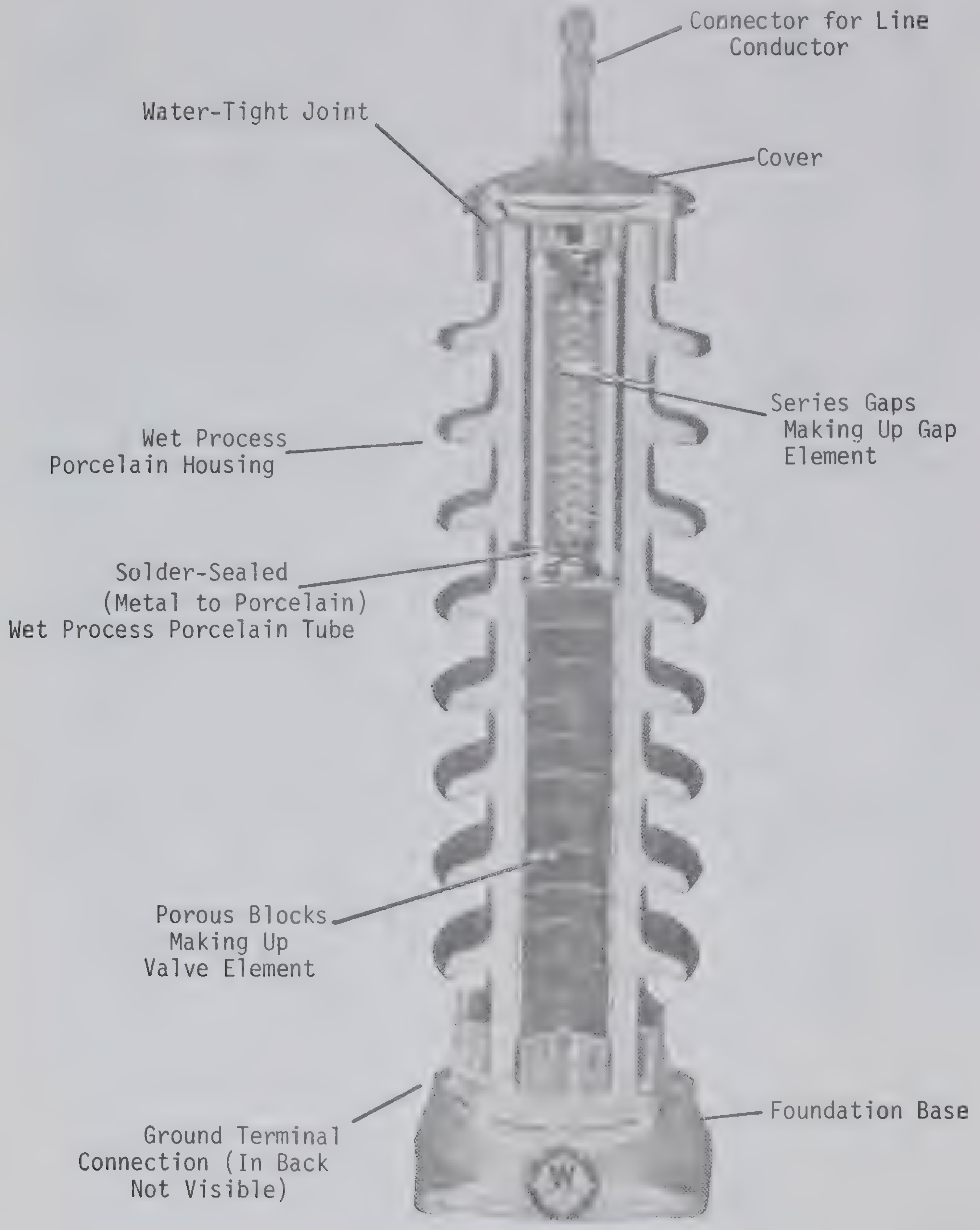


Figure 7: Hz-Type High-Speed Three-Zone Impedance Relay


RELAY TUBE
RESTRAINING VOLTAGE FROM CARRIER
OPERATING VOLTAGE FROM TRIGGER CIRCUIT
T
−
+
+
−
R
E_c
D.C. SUPPLY

Simple Relay Circuit


Connector for Line Conductor
Water-Tight Joint
Cover
Series Gaps Making Up Gap Element
Wet Process Porcelain Housing
Solder-Sealed (Metal to Porcelain) Wet Process Porcelain Tube
Porous Blocks Making Up Valve Element
Foundation Base
Ground Terminal Connection (In Back Not Visible)

Lightning Arrestor in Sectional View

Figure 8

I3: Superconductivity

It was discovered in the early nineteenth century that metallic conductors of electricity, when cooled to very low temperatures, lose all electrical resistance. This material state is called superconductivity; conductors in this state are called superconductors, and can be used for underground transmission. Temperatures in the range needed to cause superconductivity are expressed in degrees Kelvin (K), which corresponds with the Centigrade (C) temperature scale: 273^{0} K=0^{0}C, 0^{0}K=-273^{0}C.

Kamerlingh-Onnes concluded from research he had performed that mercury, when cooled below 4.2^{0}K, enters the superconducting state (Hein 1974). They called the temperature at which a metal enters this state its transition temperature (T_0). Since transition temperatures for metal conductors are very low, it is not possible to cool conductors to T_0 with conventional refrigeration techniques. It is possible to achieve T_0 for certain conductors by cooling them with gases in a liquid state.

The temperature at which any gas, when cooled, changes to a liquid state (or at which any liquid, when heated, changes to a gas) is called the normal boiling point (NBP) of that gas. The NBP of oxygen is 90^{0} K, of hydrogen 20^{0} K, and of helium 4.2^{0} K. It is possible to reduce these gases to their NBP, thus changing them to a liquid state. Since the NBP of helium and the T_0 of mercury are identical, a conductor made of mercury can be cooled to the superconducting state by surrounding it with liquid helium.

Electric Power Transmission: As demand for electric power grows, the capacity of transmission lines needs to be increased. This formula governs such increases:

$$P=VA \cos\phi$$

where: P = power transfer

V = line voltage

A = line current rating

ϕ = phase angle between V and A

Because increasing current in a conductor can result in greater ohmic losses, the tendency has been to increase line voltage when an increase in the power rating of a transmission line is desired. The greater the voltage of a line, though, the greater the environmental impact, and the increasing use of EHV overhead lines has resulted in negative public reactions.

The great advantage of superconductivity in this respect is that since R = zero, the power rating (VA) of a line can be maximized by increasing the line current (A) several times, making it unnecessary to increase voltage. Another advantage is that power loss in superconducting A.C. lines is significantly low. Power loss in superconducting A.C. lines is calculated with this formula (Hein 1974):

$$Q = fAE_{ci} \ (H_p/H_{ci})^x$$

where: f = frequency

A = surface area

E_{ci} = a constant

H_p = peak A.C. field at the surface

H_{ci} = lower critical magnetic field

x = 3 if $H_p<H_{ci}$, 4 if $H_p>H_{ci}$

From this equation, it can be seen that for any particular value of H_p, maximum power transfer (at gigawatt level) with minimum power loss and without exceeding the thermal limit of the cable requires a high value of E_{ci} and a low value of H_{ci}.

Other advantages of the use of superconducting cables include greater critical lengths for A.C. cables, smaller size cables and greater power density.

Superconductivity is impractical at this time because of the inadequacy of present technology. New technologies must be developed to facilitate the elaborate thermal insulation and refrigeration made necessary by the low operational temperatures. The cable design itself presents problems, particularly the design of the cryogenic envelopes to surround the conductor. When these design problems are solved, then superconducting cable will become economically competitive with such existing cables as SF_6-cooled cables and high-pressure oil-filled cables.

Table 1 summarizes superconductivity research presently underway.

TABLE 1

SUPERCONDUCTING POWER CABLE PROGRAMS

Austria (Grey):		
Institute for Low-Temperature Research	Flexible A.C.	Nb Pb
Canada (Varennes):		
Hydra Quebec Research Institute	Various	under study
France (Grenoble):		
Centre-de-Recherches de la CGE and Air Liquide France	Semiflexible, D.C. and A.C.	NbTi/Al Nb/Al
Japan (Tokyo):		
Furukawa Electric Company	Rigid A.C., D.C.	NbTi/Nb/Cu Nb/Cu
Soviet Union (Moscow):		
GM Krzhijhanovsky Power Engineering Institute	Rigid A.C.	Nb Nb_3Sn
United Kingdom (Leatherhead-Surrey):		
Central Electricity Research Lab	Rigid A.C., D.C.	NbTi/Nb/Cu NbZr/Nb/Cu
	Semiflexible A.C., D.C.	Nb/Al Nb/Cu
United States:		
Union Carbide, Linde Division	Rigid A.C.	Nb/Cu
Brockhaven National Lab	Flexible A.C.	Nb/Al Nb_3Sn/Al
Los Alamos Scientific Lab	(Not Known) D.C.	Nb_3Sn/Al and other type II

Stanford University	Semiflexible A.C.	Nb_3Sn/Al and other type II
West Germany:		
(Erlangen): Siemens Company	Rigid and Semiflexible A.C., D.C.	Nb/Al Nb_3Sn/Al
(Frankfurt): Allgemeine Elektrizitats Gesellschaft, Kabelonetal Linde	Flexible D.C.	Nb_3Sn/Al

Source: Hein 1974

I4: PERFORMANCE CAPABILITIES AND PARAMETERS OF 2000 MCM PAPER-INSULATED OIL-PIPE-TYPE CABLE SYSTEMS SUMMER RATINGS

(1) Capabilities as Limited By Thermal Conditions	Nominal System Voltages-KV 69	 138	 230	 345
100% Load Factor Steady Load 3-phase thermal rated capability				
mva	105	200	330	440
amperes	880	840	830	740
75% Load Factor (62.5% daily loss factor) 3-phase thermal rated capabilities				
mva	120	230	370	500
amperes	990	950	930	840
Total permissible peak loss, including dielectric loss (75% load factor rating) watts/cond. ft.	10.34	10.35	10.35	10.06
Total permissible average loss, including dielectric loss (75% load factor rating) watts/cond. ft.	6.66	6.96	6.99	7.30
Dielectric loss watts/cond. ft.	0.54	1.36	1.40	2.68
Ratio, dielectric to total permissible average loss (75% load factor)	0.081	0.195	0.201	0.367
Ratio, loss available for conductor current to total permissible average loss (75% load factor)	0.919	0.805	0.799	0.663

I4 - continued

(2) Capabilities as Limited by Circuit Lengths

Thermal rated capability 100% load factor mva	105	200	330	440
3-phase charging reactive power mvar/mile	1.9	4.9	8.8	17.0
Critical length uncompensated--miles	55	41	38	26
Max. permissible power delivered to unity power factor load (100% load factor) uncompensated				
20 Mile line mw	98	173	280	280
Percent of thermal rating	93	87	85	64
30 mile line mw	89	134	196	0
Percent of thermal rating	84	67	59	--

(3) Cable Parameters

Insulation wall thickness, mils	285	505	835	1025
Dielectric Constant	3.7	3.7	3.5	3.5
Dielectric Power Factor, Percent	0.45	0.45	0.25	0.25
Nominal Pipe Size--inches	6-5/8	8-5/8	10-3/4	10-3/4

Note: Ratings are based on thermal resistivity of soil of 90°C-cm/watt 4 ft. depth of burial; effective loss factors for 75% load factor; conductor maximum normal temperature of 75°C; and summer maximum earth ambient temperature of 25°C.

Source: FPC 1966

I5 Reserve Margins for Northwest Power Pool Systems

(Reprinted from Western Systems Coordinating Council 1974)

1. Peak reserve requirements are the greater of
   (a) Forced Outage Reserve...plus one half year load growth for utility type load or

   (b) 12% for the first year, increasing 1% per year to 20%, and remaining at 20% thereafter. This same procedure would be repeated in subsequent years.

2. Load estimates for all utilities should be based on a 50/50 probability of occurrence with diversity taken into account on a System's own load. For resource planning purposes, the area's firm load will include BPA's peak and energy interruptible industrial load.

3. Peak reserve requirements are assumed to cover any scheduled hydro maintenance over the annual peak. For the period under consideration, thermal maintenance would not be scheduled over the annual peak.

4. The 1936-37 historical water year is to be used for determining January hydro peaking capability. Forced Outage Reserve determinations shall be made on this year with maintenance shifted to insure that January is the most critical month in the critical peaking period.

5. Each system may reduce its hydro peaking capacity to more nearly represent the capacity that can actually be realized.

6. Energy reserve requirements are based on one half year load growth of utility type energy load. Additional energy reserve is provided by limiting thermal units in excess of 500 MW capacity to a 60% load factor for the first year of commercial operation and to 75% after the first year.

Those systems serving customers in Utah, Montana, southern Idaho and Wyoming have a multiparty agreement directed toward the joint sharing of costs and output from large thermal units. This contract includes the provision for each party to maintain not less than 10% of its estimated system annual peak firm load as reserve capacity. This agreement will terminate during 1974. These systems are currently negotiating a contract with systems in the West Group. This contract will provide Forced Outage Reserve similar to that described above.

The Northwest Power Pool is a pronounced winter peaking load area. This characteristic results in high capacity reserve margins during the summer peak load period. These margins vary from 20.1% to 47.6% of firm peak load after firm transfers and scheduled maintenance outages. Some of this excess capacity will be used in generating energy to serve secondary markets and interruptible loads.

I6 Worst Case Calculations

A. Worst Case RFI Calculations (Also Applicable to TVI)

1. Methods of Calculation

For all methods listed below, the following values are used:

G_m = critical voltage gradient theoretical average value
= 17.5 KV_{rms}/ cm

G_a = critical voltage gradient theoretical rms value
= 13 KV_{rms}/ cm

d= conductor diameter = 1.14" (2.895 cm)
N= no. of conductors per phase = 4
D= distance from line = 100' to 1000'
(30.48m to 304.8m)
H= average altitude = 5000' (1538m)

Additional values for individual methods will be listed with each method.

For all methods, E is directly proportional to RFI and TVI and is a dependent function on distance (D).

All methods of calculation were taken from the "Comparison of Radio Noise Prediction Methods with CIGRE/IEEE Survey Results" (IEEE Radio Noise Subcommittee 1972).

a. Method I

$$E = 53.7 \pm 5 + K\,(G_m - 16.95) + 40 \log \frac{d}{3.53} + E_n + E_f + 32 \log\left(\frac{20}{D}\right) + E_{fw}$$

$$= 69.18 \pm 8 + 32 \log\left(\frac{20}{D}\right)$$

Where:

K = a constant = 3.5

E_n = correction factor for no. of conductors = 0

E_f = correction factor for frequency = 0

E_{fw} = correction factor for foul weather = 17 ± 3

b. Method II

$$E = \left[10.5\ G_p - \left(\frac{G_p}{2}\right)^2 - 31\right] + 40 \log \frac{2.895}{2.53} + 20 \log\left(\frac{h^2}{D}\right)$$

$$= 60 + 20 \log \left(\frac{11.24}{D}\right)^2$$

Where: G_p = Critical voltage gradient for bottom conductor

= 16.84

c. Method III

$$E = 47 + 3.8\ (G_a - 15) + 40 \log \frac{d}{5} + 10 \log N$$

$$+ 30 \log\left(\frac{20}{D}\right) + E_f + E_q$$

$$= 52.944 + 30 \log \left(\frac{20}{D}\right)$$

Where:

$E_f = 0$

E_q = correction factor for elevation = 5.126

d. Method IV

$$E = 11 + 4.5\ G_m - 34 \log D + E_{fw} + 20$$

$$= 89.75 - 34 \log (D) + E_{fw}$$

Where: $E_{fw} = 20$

2. Results

Table 1 shows predicted values of RFI or TVI, in decibels, for fair and foul weather, by all four methods of calculation. For comparison with SNR ratings, see Section 4.4.2.

Table 1

D-distance from center		Method - I $69.18 \pm 8+32\log\left(\frac{20}{D}\right)$		II $60+20\log\left(\frac{11.24}{D}\right)^2$	III $52.944+30\log\left(\frac{20}{D}\right)$	IV $\underbrace{89.75-34\log(D)}_{A}\ \underbrace{+E_{fw}}_{B}$	
		$77.18+32\log\left(\frac{20}{D}\right)$	$61.18+32\log\left(\frac{20}{D}\right)$			A	A + B
D in feet	D in meters	in DB (foul weather)	in DB (fair weather)	in DB (50% fair weather)	in DB (50% foul weather)	in DB (fair weather)	in DB (foul weather)
100	30.48	71.324	55.325	42.67	67.454	32.293	59.293
200	60.96	61.691	45.69	30.62	38.423	29.058	49.058
300	91.44	56.049	40.057	23.58	33.140	23.071	43.071
400	122	52.049	36.05	18.57	29.384	18.814	38.814
500	152.4	48.95	32.96	14.71	26.485	15.528	35.528
600	183	46.44	30.42	11.53	24.101	12.827	32.827
700	213	44.305	28.31	8.89	22.123	10.535	30.535
800	244	42.416	26.416	6.535	20.353	8.579	28.579
900	274	40.805	24.81	4.52	18.842	6.866	26.866
1000	304.8	39.324	23.33	2.67	17.454	5.293	25.293

B. Worst Case Electrostatic Effects Calculations

1. Inductive Coupling

Figure 1 shows the position of conductors for the two proposed lines, and the position in relation to the conductors of the four fences for which calculations were made.

a. Fence #1

The fence was assumed to be located midway between the two power lines.

$$V_{oc} = -j(.2794)\Big[I_1 \log D_{IF} + I_2 \log D_{2F} + I_3 \log D_{3F}$$
$$+ I_4 \log D_{4F} + I_5 \log D_{5F} + I_6 \log D_{6F} \Big] \qquad \text{(Westinghouse 1964, p. 748)}$$

where all logarithms are base 10.

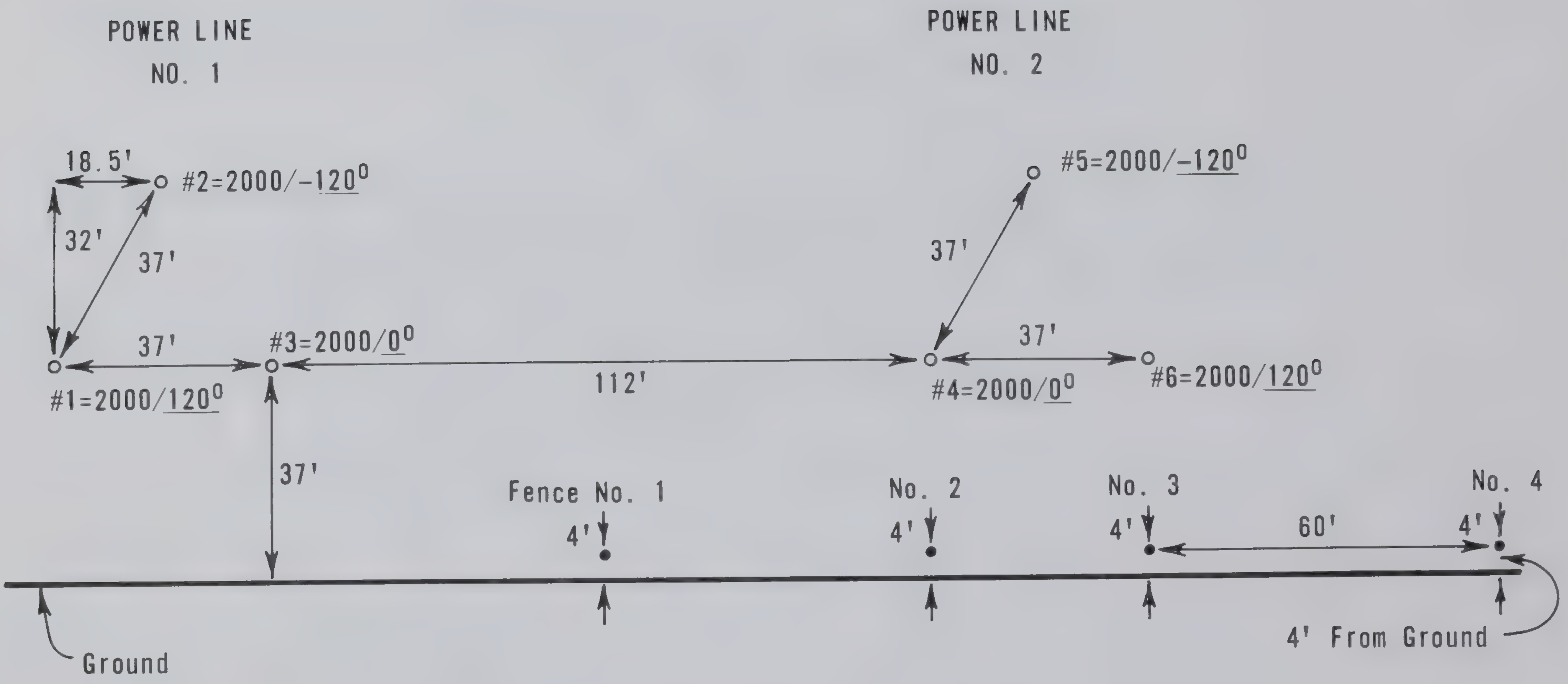
$$D_{1F} = \Big[(56 + 37)^2 + (37-4)^2\Big]\ 1/2 = 98.68 \text{ ft.}$$

$$D_{2F} = \Big[(56 + 18.5)^2 + (37-4 + 32)^2\Big]\ 1/2 = 98.86 \text{ ft.}$$

$$D_{3F} = (56^2 + 33^3)\ \ 1/2 = 65 \text{ ft.}$$

$$D_{4F} = D_{3F} \qquad D_{5F} = D_{2F} \qquad D_{6F} = D_{1F}$$

$$V_{oc} = -j(.2794)\Big[(2000\ \underline{/\ 120^\circ}\ ) \log 98.68 + 2000\ \underline{/-120^\circ}\ \log 98.86$$
$$+ 2000\ /0^\circ\ (65) + 2000\ \underline{/0^\circ}\ (65) + 2000\ \underline{/-120^\circ}\ \log 98.86$$
$$+ 2000\ \underline{/120^\circ} \log 98.68\Big] \quad \text{volts/mile}$$
$$= -j(558.8)\Big[(-.5 + j.866)\ \ (\log 98.68 + \log 98.68)$$
$$+ (1)\ (\log 65 + \log 65) + (-.5 - j.866)\ (\log 98.86 + \log 98.86)\Big]$$
$$= -j(1117.6)\Big[\ (-.5 + j.866)\ (3.988)$$



DIFFERENT LOCATIONS OF FENCE

FIGURE 1

$$+ 3.625 + (-.5 - j.866)\ (3.99)\Big]$$

$$= -J(1117.6)\ \Big[-1.995 + j3.95 + 3.625 - 1.995 - j3.45\Big]$$

$$= -j(1117.6)\ \Big[-.365 + 0\Big]$$

$$= j(407.92) \text{ volts/mi}$$

or $V_{oc} = 407.92\underline{/9^{0}}$ volts/mi

Because fences generally do not parallel lines for a full mile, and because the 2000 amp current will generally not exist in the conductor all the time, a correction factor of .25 has been applied to this worst-case value to give an average-case value:

$$V_{correction} = 407.92\ \underline{/90^{0}} \times .25 = 101.92\ \underline{/90^{0}}$$

b. Worst Case Calculations

Calculated values for V_{oc} and $V_{correction}$ for three other fence positions are given Table 2.

Table 2

Fence Position	V_{oc}	$V_{correction}$
#1 - fence between conductors 3 & 4	$407.92\ \underline{/90^{0}}$	$101.92\ \underline{/90^{0}}$
#2 - fence under conductor 4	$312\ \underline{/110^{0}}$	$78\ \underline{/110^{0}}$
#3 - fence under conductor 6	$215.8\ \underline{/175^{0}}$	$53.95\ \underline{/175^{0}}$
#4 - fence 60' from conductor 6	$98.6\ \underline{/201^{0}}$	$24.65\ \underline{/201^{0}}$

The following factors must be considered when interpreting Table 2.

1. The figures were derived for a worst-case condition.

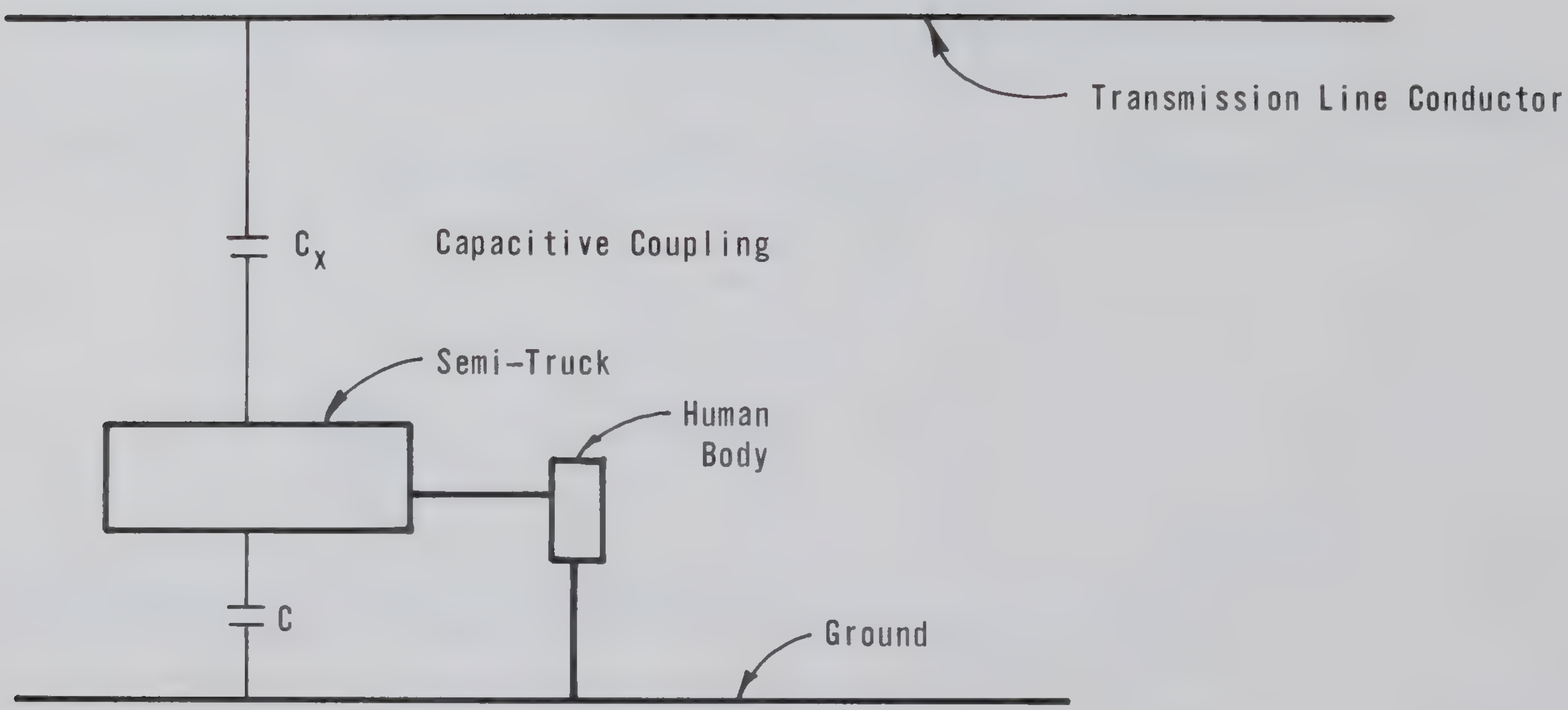
2. Actual values of V_{OC} encountered would probably be less than those calculated because few fence lines are perfectly insulated from ground.

One cannot way whether the voltages induced in the fence represent a serious hazard, since it is current and not voltage which causes injury when a person is shocked. It would be difficult to determine the amount of current which would flow through a person, since the impedance of the total current path, which includes the earth, the person, and the fence wire, cannot readily be determined. Typical values for the impedance of the human body and the earth (which varies from 10 to 1000 ohms/meter) are not specific enough to provide reliable information about the amount of current which would flow. Also, the method of calculating V_{OC} is based upon the assumption that no current is allowed to flow. Values of $V_{correction}$ were calculated considering some of these variables. If earth resistance is assumed to be 100 ohms/meter, and body resistance 300 ohms current in worst case #1 (see Table 2) would be .6mA, less than the let-go current values given in Figure 7.

2. Capacitive Coupling

A large conducting object which is located fairly close to an EHV power transmission line will have a small amount of capacitive coupling between itself and the power line. The model for the coupling is given in Figure 2. The object wil typically be insulated from ground, and hence the object to ground impedance will also be capacitive. The capacitance C_X between the power line and the object will be on the order of only a few picofarads; however, since $C = \frac{Q}{V}$ and the voltage is on the order of a few hundred kilovolts, there can be a significant charge induced on the object. The capacitance from object to ground generally represents a much higher impedance than that of a human body. Hence, the human body will represent essentially a short circuit to the charge distribution induced on the object.

There are several methods available for calculating the voltage and current induced in the object with respect to ground, most of which use a computer



CAPACITIVE COUPLING

FIGURE 4-20

to solve the problem. One method, presented by Comsa and Rene (1963b), can be used to calculate the short-circuit current I_X without the use of the computer. The method is based upon some experimental results, and it yields values for I_X which are within 5% to 12% of field-measured values (Tranen and Wilson 1971).

The method presented by Rene-Comsa doesn't calculate the open circuit voltage induced on the object; however, according to the authors, the open circuit voltages are not of great practical interest (Comsa and Rene 1968a).

The Rene-Comsa method is based upon the solution to the following matrix equation.

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_X \end{bmatrix} = -j \begin{bmatrix} X_{11} & X_{12} & X_{13} & X_{iX} \\ X_{21} & X_{22} & X_{23} & X_{2X} \\ X_{31} & X_{32} & X_{33} & X_{3X} \\ X_{X1} & X_{X2} & X_{X3} & X_{XX} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_X \end{bmatrix}$$

This equation is derived from equation 6 on page 437 of Circuit Analysis of A-C Power Systems by Clarke (1943). The values and definitions of the variables are given below.

V_1-V_3 = Phase conductor voltages w.r.t. ground

V_X = voltage induced in object w.r.t. ground

I_1-I_3 = Phase currents required to charge the line to the specified voltage.

$X_{11} = .0683 \log_{10} \frac{S_{11}}{r_1}$ M Ω/mile

from Eq. (7) on page
437 of Clarke (1943).

$X_{12} = .0683 \log_{10} \frac{S_{12}}{s_{12}}$ M Ω/mile where:

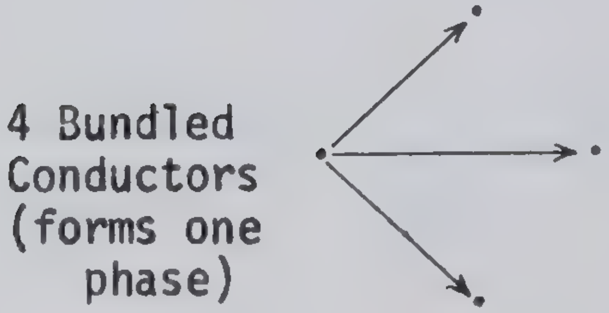
S_{11} = distance from conductor 1 to its image

S_{12} = distance from conductor 1 to the image of conductor 2

S_{12} = distance between conductors 1 and 2

r_1 = Geometric Mean Radius of the bundled phase conductor 1.

The Geometric Mean Radius (GMR) of each bundled phase conductor is calculated by the following formula:



$$GMR = \left[(r)(D_{12})(D_{13})(D_{14})\right]^{1/4}$$

where: r = the radius of each conductor

Figure 3

Rene-Comsa solve the matrix equation for I_X, which yields the following:

$$I_X = -j\omega \begin{bmatrix} C_{1X} & X_{11} & C_{2X} & X_{22} & C_{3X} & X_{33} \end{bmatrix} \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}^{-1} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

where: $\omega = 2\pi f$

The values of X_{11} through X_{33} have already been specified, and the values of C_{1X} through C_{3X} represent the capacitance between the object and the power line which must be found from empirical data.

Comsa and Rene (1968b) provide graphs (Figure 4) for determining the power line-object capacitance for long rectangular objects such as semi trailers and some farm implements. The total power line-object capacitance was found to depend upon the cross-sectional area of the object as well as its length.

For a long rectangular object located fairly close to the power lines and also situated parallel to the lines, the capacitance between the object and each phase conductor is given by:

$$C_{nx} = e_x \log_{10} \frac{S_{nx}}{s_{nx}} + \frac{(7.35)(L) \log_{10} \frac{S_{nx}}{s_{nx}}}{\log_{10} \frac{S_{nn}}{r_n} \log_{10} \frac{S_{xx}}{r_x} - \left[\log_{10} \frac{S_{nx}}{s_{nx}} \right]^2} \text{ pf}$$

where: S_{nx} = distance from phase conductor n to image of the object

s_{nx} = distance from phase conductor n to object

S_{nn} = distance from phase conductor n to image of phase conductor n

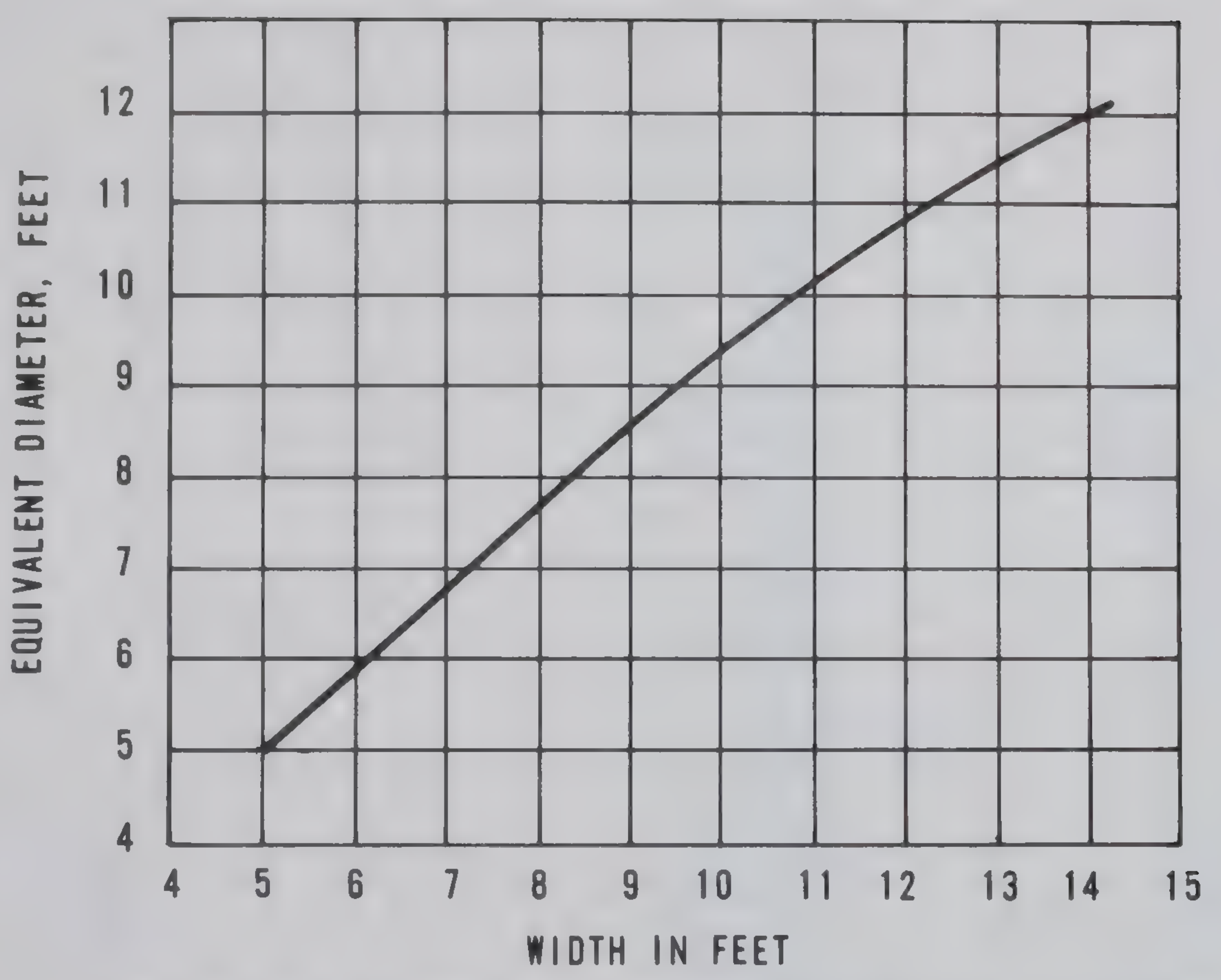
r_n = GMR of phase conductor n

S_{xx} = 2 (Height of object) - (Width of object)

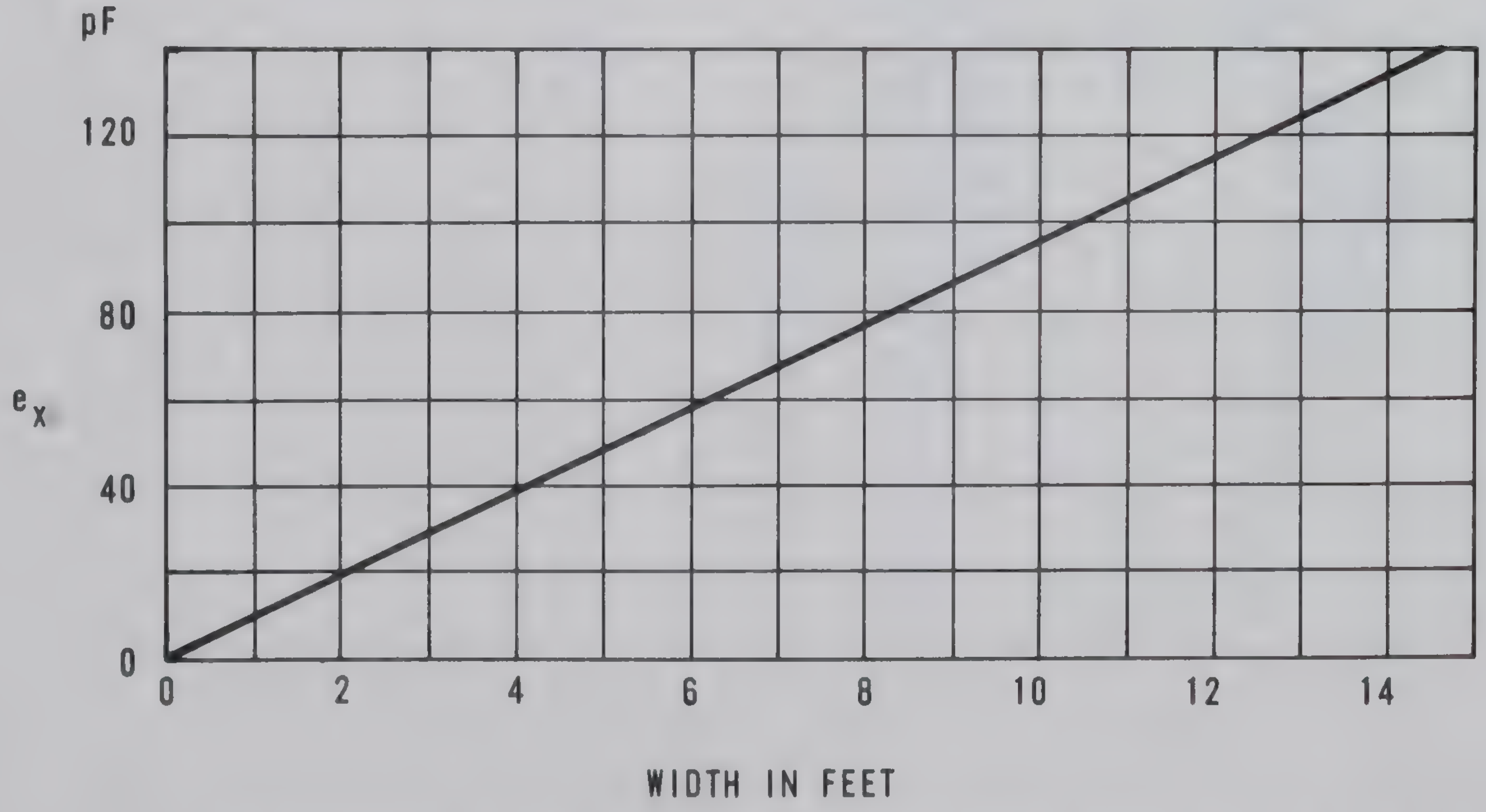
r_x = Equivalent radius of object, derived from the upper graph of Figure 4.

e_x = Capacitive end effect factor, derived from the lower graph of Figure 4.

L = Length of object in ft.



EQUIVALENT DIAMETER FOR RECTANGULAR OBJECTS OF WIDTH W



CAPACITIVE END EFFECT FACTOR FOR RECTANGULAR OBJECTS OF WIDTH W

FIGURE 4

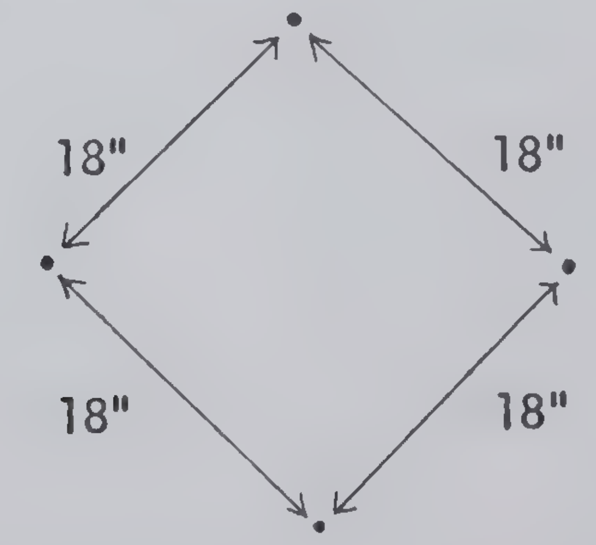
If the above capacitive terms are converted to microfarads (multiply by 10^{+6}) the current I_x will be in milliamperes if V_1 through V_3 are expressed in Kilovolts.

Following is an example of the calculation of I_x. The same conductor configuration as was used in the inductive coupling example will be used, except only one of the power lines will be considered. The object considered will be a semi-trailer (Figure 5) with the following dimensions:

Total height = 13.6 ft.
Width = 8 ft.
Length = 39 ft.

The voltages shown in Figure 5 are the approximate phase-to-ground voltage for a 500 KV transmission line. Each dot represents one bundled phase conductor which has a radius equal to the GMR for each bundled conductor.

The bundled conductors are to have the following configuration (Westinghouse 1973).



Each Conductor
1.14" in Diameter (795 MCM ACSR)

Figure 6

$$\mathrm{GMR} = \left[(r)(D_{12})(D_{13})(D_{14}) \right]^{1/4} = \left[\left[\frac{1.14}{2}\right] (18)(18)(18\sqrt{2}) \right]^{1/4}$$

$$= 8.280 \text{ inches } (.69 \text{ feet})$$

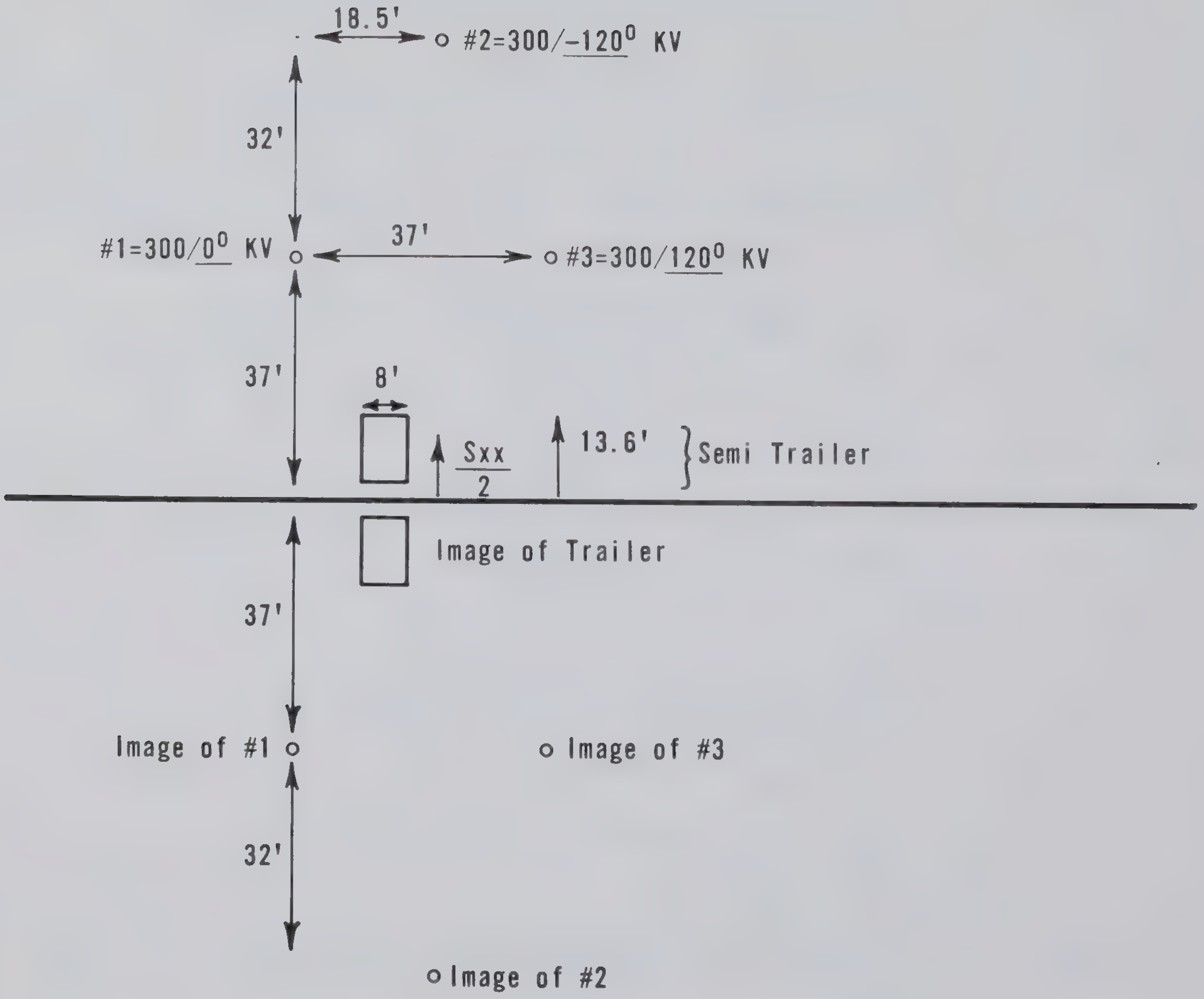

18.5'
#2=300/-120⁰ KV
32'
#1=300/0⁰ KV
37'
#3=300/120⁰ KV
37'
8'
Sxx/2
13.6'
Semi Trailer
Image of Trailer
37'
Image of #1
Image of #3
32'
Image of #2

FIGURE 5

Calculating the terms in the coefficient matrix:

$$X_{11} = .0683 \log \frac{S_{11}}{r_i} = .0683 \log \frac{(2)(37)(12)}{8.28} \simeq .13868 \ \mathrm{M\Omega/mile}$$

$$X_{12} = .0683 \log \frac{S_{12}}{s_{12}} = .0683 \log \left[\frac{(18.5)^2 + (69 + 37)^2}{(32^2 + 18.5^2)}\right]^{1/2} = .0317 \ \mathrm{M\Omega/mile}$$

$$X_{13} = .0683 \log \frac{(37^2 + 74^2)^{1/2}}{37} = .0239 \ \mathrm{M\Omega/mile}$$

$$X_{21} = X_{12} = .0317 \ \mathrm{M\Omega/mile}$$

$$X_{22} = .0683 \log_{10} \frac{(2)(69)(12)}{8.280} \simeq .15716 \ \mathrm{M\Omega/mile}$$

$$X_{23} = X_{21} = .0317 \ \mathrm{M\Omega/mile}$$

$$X_{31} = X_{13} = .0239 \ \mathrm{M\Omega/mile}$$

$$X_{32} = X_{23} = .0317 \ \mathrm{M\Omega/mile}$$

$$X_{33} = X_{11} = .13868 \ \mathrm{M\Omega/mile}$$

Inserting these terms, the coefficient matrix is: $\begin{bmatrix} .13868 & .0317 & .0239 \\ .0317 & .1571 & .0317 \\ .0239 & .0317 & .13868 \end{bmatrix}$

The inverse of the coefficient matrix is:

$$\frac{1}{2.7526 \times 10^{-3}} \begin{bmatrix} .02104 & -3.665 \times 10^{-3} & -2.771 \times 10^{-3} \\ -3.665 \times 10^{-3} & .01889 & -3.665 \times 10^{-3} \\ -2.771 \times 10^{-3} & -3.665 \times 10^{-3} & .02104 \end{bmatrix} \frac{\text{mile}}{\text{M}\Omega}$$

For the 39 ft. x 8 ft. x 13.6 ft. trailer:

$$\text{Width} = 8 \text{ ft} \qquad \begin{matrix} r_x = 7.7 \text{ ft.} \\ e_x = 75 \text{ pf} \end{matrix} \qquad \text{From Figure 4}$$

$$\frac{S_{xx}}{2} = \text{equivalent vehicle ht.} = H - \frac{W}{2} = 13.6 - \frac{8}{2} = 9.6 \text{ ft.}$$

$$C_{1x} = \frac{(7.35) \quad \log \frac{S_{1x}}{s_{1x}} \quad L}{\log \frac{S_{11}}{r_i} \quad \log \frac{S_{xx}}{r_x} - \left(\log \frac{S_{1x}}{s_{1x}}\right)^2} \quad \text{pf.}$$

or

$$C_{1x} = C_{3x} = \frac{(7.35)(39) \quad \log \left[\frac{18.5^2 + (37 + 9.6)^2}{18.5^2 + (37 - 9.6)^2}\right]}{\log \frac{(37)(2)(12)}{8.05} \quad \log \frac{(2)(9.6)}{7.7} - \left[\log \frac{2513.8}{1093.0} \; 1/2\right]^2}$$

$$= 66.65 \text{ pf}$$

$$C_{1x} = C_{3x} = 66.65 \text{ pf} + 75 \log \frac{S_{1x}}{s_{1x}} = 80.21 \text{ pf.}$$

$$= (.08021 \times 10^{-3} \ \mu\text{f})$$

$$C_{2x} = \frac{(7.35)(39) \ \log \left[\dfrac{69 + 9.6}{69 - 9.6} \right]}{\log \dfrac{(2)(69)(12)}{8.05} \quad \log \dfrac{(2)(9.6)}{7.7} \ - \left[\log \left[\dfrac{69 + 9.6}{69 - 9.6} \right] \right]^2}$$

$$= 38.61 \text{ pf}$$

$$C_{2x} = 38.61 \text{ pf} + 75 \text{ pf} \log \left[\frac{S_{2x}}{s_{2x}} \right] = 47.74 \text{ pf} = (.04773 \times 10^{-3} \ \mu\text{f})$$

therefore:

$$I_x = -jw \begin{bmatrix} C_{1x}X_{11} & C_{2x}X_{22} & C_{3x}X_{33} \end{bmatrix} \begin{bmatrix} \text{Coefficient matrix} \end{bmatrix}^{-1} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

$$I_x = -j377 \Big[(.08021 \times 10^{-3})(.1395) \quad (.04773 \times 10^{-3})(.1580) \quad (.08021 \times 10^{-3})(.1395) \Big].$$

$$\frac{1}{2.7526} \begin{bmatrix} 21.04 & -3.665 & -2.771 \\ -3.665 & 18.89 & -2.665 \\ -2.771 & -3.665 & 21.04 \end{bmatrix} \begin{bmatrix} 300 \ \underline{/\ 0^{o}} \\ 300 \ \underline{/-120^{o}} \\ 300 \ \underline{/\ 120^{o}} \end{bmatrix} \text{ mA}$$

$$I_x = 4.82 \ \underline{/-30^{o}} \ \text{ mA.}$$

Other cases were also calculated for the same conductor configuration, but for different positions of the semi-trailer (dimensions--H = 13.6' W = 8', L = 39'). The results are summarized in Table 3.

Table 3

Case	Trailer Location	I_x
I	between conductors #1 and #3	$4.82\ \underline{/-30^{\circ}}$ mA
II	under conductor #1	$8.14\ \underline{/-84.6^{\circ}}$ mA
III	50 ft. outside conductor #1	$1.93\ \underline{/-109.6^{\circ}}$ mA
IV	60 ft. outside conductor #3	$1.68\ \underline{/-114.8^{\circ}}$ mA

Table 4 contains I_x calculations for a much smaller vehicle, a medium-sized car (dimensions--H =6', W=5.6', L=16').

Table 4

Case	Car Location	I_x
I	between conductors #1 and #3	$1.24\ \underline{/150^{\circ}}$ mA
II	under conductor #1	$2.09\ \underline{/60^{\circ}}$ mA
III	50 ft. outside conductor #1	$0.45\ \underline{/60^{\circ}}$ mA
IV	60 ft. outside conductor #3	$0.25\ \underline{/-120^{\circ}}$ mA

From cases III and IV in Tables 3 and 4, it can be seen that electrostatic induction in a trailer or automobile does not represent a serious hazard for distances greather than 50 ft. from the transmission line. Case IV indicates that electrostatic induction will not be significant if the vehicle is outside the right-of-way of the transmission lines.

One can obtain the value for I_x for a vehicle parked in the center of the right-of-way for the conductor configuration given in Figure 2 by doubling the value for I_x found for case III above. This yields a value of $I_x = 3.86\ \underline{/-109.6^{\circ}}$ mA for a semi-trailer, and $.9\underline{/60^{\circ}}$ mA for an automobile.

Also, from Case II, it can be concluded that the highest values of I_x occur when the trailer is positioned directly below one of the phase conductors and parallel to the conductor. The value of $I_x = 8.14\ \underline{/-84.6^{\circ}}$ mA is higher than the let-go current for women and children (Figure 7).

Comsa and Rene (1968a) list the following values for safe let-go currents:

Men = 9 mA

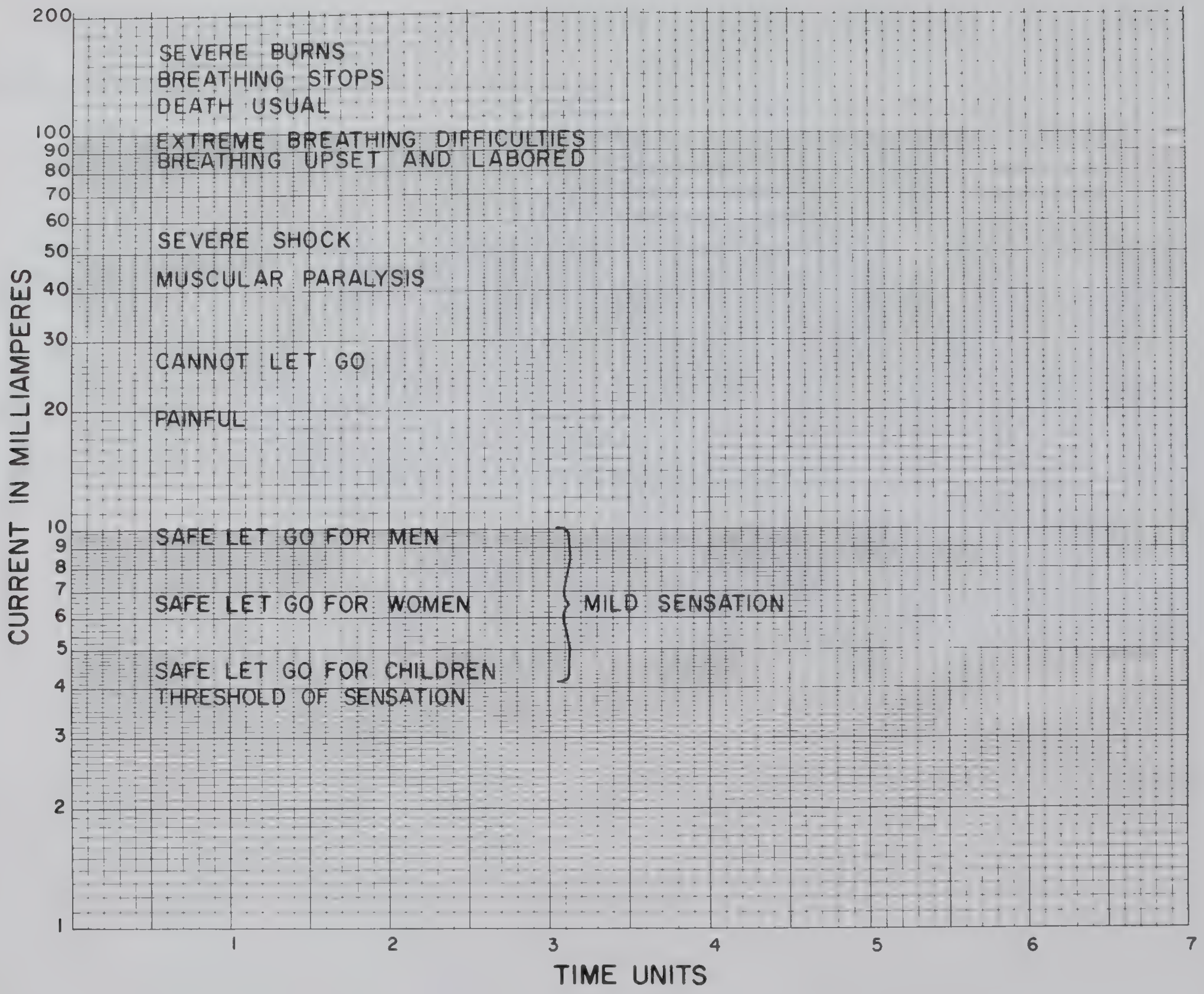
Women = 6 mA

Children = 4.5 mA

Let-go current is defined as the maximum current at which a human still has voluntary control of the area of his body in which the current is flowing. A human cannot let go of the object which is shocking him if the current passing through his body is greater than his let-go current. Generally (see Figure 7), an individual will experience only a mild sensation at his let-go current level.

The calculations given above are subject to the following qualifications:

1. The object must be parallel to the line. Values for I_x will be



EFFECTS OF CURRENT ON HUMANS

Source: Popular Science, 1972 and Rene-Coma IEEE Paper

FIGURE 4-21

less than predicted if the object is located at an angle with respect to the power lines.

2. The object must be well insulated from ground, or the value of I_x will be less than predicted.

3. Switching transients on the line can almost double the phase voltages on the line for a short time. This effect can also cause a transient value of I_x which is many times the predicted value. Little is known about the effects of impulse current on the body.

4. The examples were done for a worst-case condition of a conductor height of 37' at mid-span. As the value of I_x is more or less inversely proportional to the distance between the object and the power lines, the value of I_x would go down for conductor heights of more than 37'.

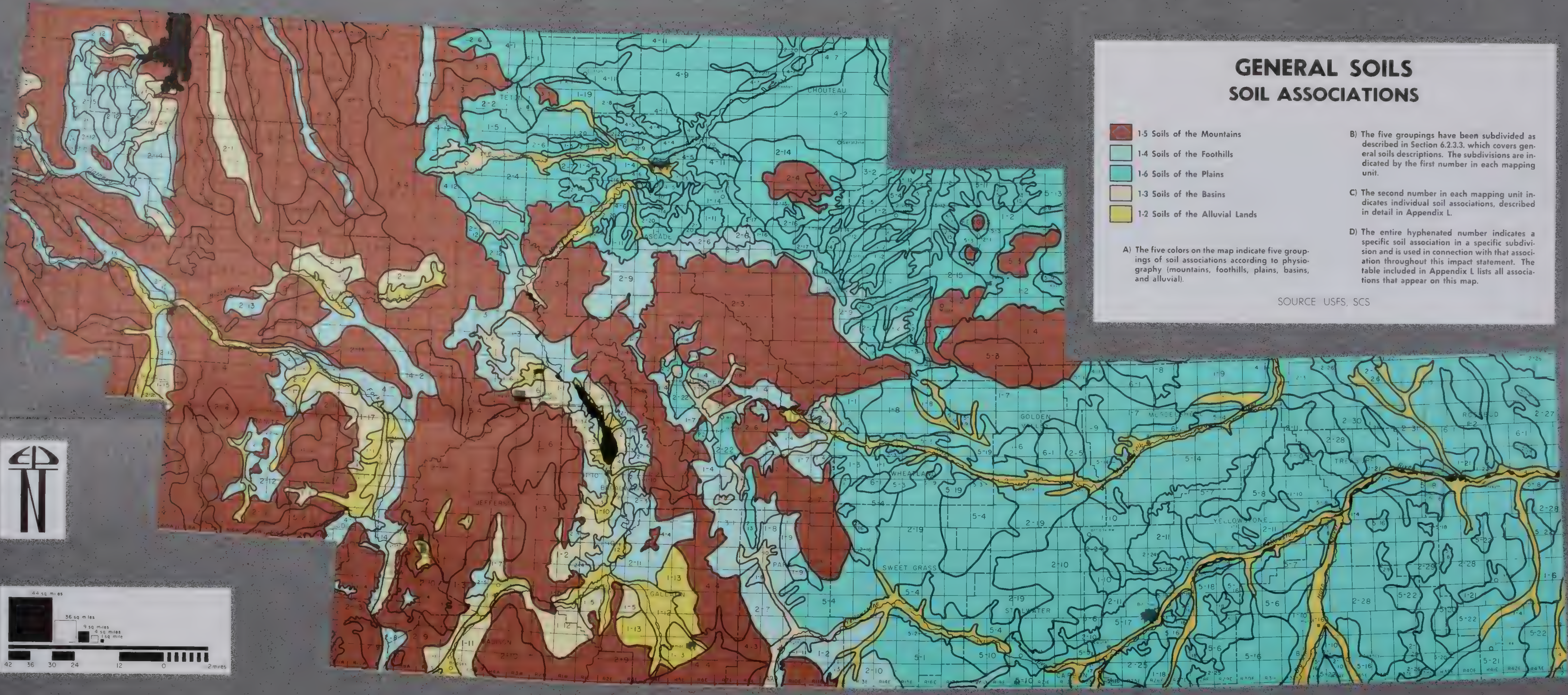
APPENDIX J: General Soils Map

Explanation to the General Soils Map

The General Soils Map for the transmission line study area covers nearly two thirds of the state. Soil Association maps (1:500,000 scale) constructed and published by the Soil Conservation Service were used to draft the soil associations that appear on the map. The associations were grouped according to type of physiography as described in Section 5.1.3.3. (Mountains #1-5, foothills #1-4, etc.). Table 1 contains detailed descriptions of associations that appear in the study area. Dominant soil series (the level of soil classification of which detailed impact interpretations are made) are listed for each association in which they appear. The subgroup and textural family for each series are also listed, along with the county in which the association appears. Impact parameters (percentage of coarse fragments, depth to bedrock, pH fertility, shrink/swell, and tilth) are listed when data is available for each series. Impact interpretations, such as compacted soil erosion hazard, and suitability ratings for tower foundations, access roads, and right-of-ways, are also shown for each association. All of this data is necessary to make thorough impact analysis for corridor selection (refer to Sections 5.3.3. and 6.1.3.).

Table Symbols

The following list explains the symbols and abbreviations used in Table 1:



GENERAL SOILS
SOIL ASSOCIATIONS

🟥 1-5 Soils of the Mountains
🟦 1-4 Soils of the Foothills
🟦 1-6 Soils of the Plains
☐ 1-3 Soils of the Basins
🟨 1-2 Soils of the Alluvial Lands

A) The five colors on the map indicate five groupings of soil associations according to physiography (mountains, foothills, plains, basins, and alluvial).

B) The five groupings have been subdivided as described in Section 6.2.3.3. which covers general soils descriptions. The subdivisions are indicated by the first number in each mapping unit.

C) The second number in each mapping unit indicates individual soil associations, described in detail in Appendix L.

D) The entire hyphenated number indicates a specific soil association in a specific subdivision and is used in connection with that association throughout this impact statement. The table included in Appendix L lists all associations that appear on this map.

SOURCE USFS, SCS

Soil Taxonomy:

mont.--montmorillonitic
calc.--calcareous

Impact Parameters:

H--high M--medium L--low
n.g.--native grassland
n.r.--native rangeland
r--rangeland
cult--cultivated
past--pasture

Impact Interpretations:

Erosion Hazard Categories
S--severe
M--moderate
SL--slight

Suitability Rating Categories:

G--good
F--fair
p--poor

TABLE 1

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit#	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
Soils of the Mountains #1-5													
1-1	Mucet	Lithic Cryoboroll	loamy-mixed	Cascade						M	F	F	F
	Behavin	Pachic Cryoboroll	loamy-skeletal, mixed										
	Blaine	Argic Cryoboroll	loamy-skeletal, mixed		35-80	20-40	7.9-8.4	L	R				
1-2	Cheadle	Lithic Cryoboroll	loamy-skeletal, mixed	Broadwater		< 20	7.4-8.4	L	n.g.	M	F	F	F
	Neilson	Argic Lithic Cryoboroll	loamy-skeletal, mixed			10-20	6.7-7.4		R				
	Ess	Argic Cryoboroll	loamy-skeletal, mixed										
1-3	Sappington	Aridic Argiboroll	coarse-loamy, mixed	Jefferson	5-30		7.6-8.6		cult.	M	F	F	F
	Penrose	Lithic Ustic Torriorthent	loamy, mixed, calcareous										
1-4	Alder	Udic Argiboroll	fine, mixed	Fergus		20-40	5.6-7.3	L		M	F	F	F
	Sipple	Udic Argiboroll	fine-loamy, mixed			>40			cult.				
	Cheadle	Lithic Cryoboroll	loamy-skeletal, mixed			<20	7.4-8.4	L	n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
1-5				Meagher						M	F	F	F
2-1				Sweetgrass & Stillwater						M	F	F	F
2-2	Bridger	Argic Cryoboroll	fine, mixed	Judith Basin	5-30		6.6-8.4	L		M	F	F	F
	Woodhurst	Argic Pachic Cryoboroll	loamy-skeletal, mixed		10-40	20-40	7.6-8.3	L	tim				
	Spring Creek	Lithic Cryoboroll	loamy-skeletal, mixed				7.4-8.4	L	n.g.				
2-3	Hughesville	Typic Cryoboroll	fine-loamy, mixed	Cascade & Judith Basin		20-40	8.4-8.8	L	n.R.	M	F	F	F
	Whitore	Typic Cryochrepts	loamy-skeletal, carbonatic		25-50	< 40			F				
	Duncom	Lithic Cryoboroll	loamy, mixed				8.0-8.6	L	R				
2-4	Cowood	Lithic Cryochrept	loamy-skeletal, mixed	Chouteau		12-20	5.1-6.0	L	tim	M	F	F	F
	Sapphire	Typic Cryoboralf	fine-loamy, mixed			20-40	6.1-7.8	L	n.g.				
	Tigeron	Typic Cryoboralf	loamy-skeletal, mixed			> 60	5.2-5.6		f				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-5	Lake Creek	Typic Cryoboralf	loamy-skeletal, mixed	Broadwater	35-70	20-40	6.5-7.0		R	M	F	F	F
	Whitore	Typic Cryochrept	loamy-skeletal, carbonatic		25-50	< 40			F				
	Loberg	Typic Cryoboralf	clayey-skeletal, mixed		35-50		5.1-7.8	L	n.R.				
2-6				Meagher						M	F	F	F
2-7	Teton	Typic Cryoboroll	fine-loamy,mixed	Park	2-30	24-40	6.0-7.8	L	cult.	M	F	F	F
	Sapphire	Typic Cryoboralf	fine-loamy,mixed			20-40	6.1-7.8	L	n.g.				
2-8	Loberg	Typic Cryoboralf	clayey-skeletal, mixed	Gallatin	35-50		5.1-7.8	L	n.R.	M	F	F	F
	Leavitt	Argic Cryoboroll	fine-loamy,mixed				7.0-8.2		g				
	Hanson	Calcic Cryoboroll	loamy-skeletal, carbonatic				6.5-8.5		n.g.				
2-9	Blaine	Argic Cryoboroll	loamy-skeletal, mixed	Madison	35-80	20-40	7.9-8.4	L	R	M	F	F	F
	Nagisty	Pachic Cryoboroll	loamy-skeletal, mixed			20-40	6.2-6.5		R				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-10	Loberg	Typic Cryoboralf	clayey-skeletal, mixed	Madison	35-50		5.1-7.8	L	n.R.	M	F	F	F
	Woodrock	Typic Cryoboralf	fine-loamy, mixed		15-35	20-40	5.2-5.4		F				
2-11	Holloway	Andic Cryochrept	loamy-skeletal, mixed	Granite, Missoula & Sanders	50-80		4.5-6.4		F	M	G	F	F
	Garlet	Typic Cryochrept	loamy-skeletal, mixed			60-80	6.0-6.8		F				
	Winkler	Udic Ustochrepts	loamy-skeletal, frigid		15-35	> 40	6.0-7.0		F				
2-12	Holloway	Andic Cryochrepts	loamy-skeletal, mixed	Granite & Sanders	50-80		4.5-6.4		F	M	G	F	F
	Blackleed	Typic Cryochrept	loamy-skeletal, mixed			20-40	6.6-7.0						
2-13	Ambrant	Udic Ustochrept	coarse-loamy, mixed, frigid	Granite & Jefferson						M	G	F	F
	Elkner	Andic Cryochrept	coarse-loamy, mixed		5-35	> 60	5.8-6.2		F				
	Ashton	Uthic Ustochrept	loamy-skeletal, mixed, nonacid										
2-14	Alpine									M	G	F	F

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations	Suitability Ratings		
Ser-ies Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Skrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-15	Tolman	Lithic Argiboroll	loamy-skeletal, mixed	Lewis & Clark	35-75	10-20	6.4-6.8		g	M	G	F	F
	Castner	Lithic Haploboroll	loamy-skeletal, mixed		50-70	6-20	7.2-8.4		n.g.				
2-16	Stecum	Typic Cryorthent	sandy-skeletal, mixed	Jefferson		12-36	7.0-7.4		F	M	G	F	F
	Spring Creek	Lithic Argiboroll	loamy-skeletal, mixed				7.4-8.4	L	n.g.				
	Penrose	Lithic Ustic Torriorthent	loamy, mixed, calc., mesic										
2-17	Felan	Andic Cryochrept	loamy-skeletal, mixed	Deer Lodge			5.6-6.0		tim	M	G	F	F
	Trappen	Typic Cryoboralf	fine-loamy, mixed										
	Repp	Typic Ustochrept	loamy-skeletal, mixed, frigid			10-20	8.0-8.5		F				
2-18				Powell & Missoula						M	G	F	F

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
3-1	Whitore	Typic Cryochrept	loamy-skeletal, carbonatic	Teton	25-50	<40			f	M	P	P	P
	Loberg	Typic Cryoboralf	clayey-skeletal mixed		35-50		5.1-7.8	L	n.g.				
	Garlet	Typic Cryochrept	loamy-skeletal, mixed			60-80			f				
3-2	Burnett	Argic Pachic Cryoboroll	fine, montmorillonitic	Teton						M	P	P	P
	Hanson	Calcic Cryoboroll	loamy-skeletal carbonatic				6.5-8.5		n.g.				
	Michaelson	Argic Cryoboroll	fine-loamy, mixed		5-40	30-40	6.6-7.5		n.g.				
3-3	Raynesford	Calcic Cryoboroll	fine-loamy, carbonatic	Teton	10-40	>60	7.9-8.6	L	n.g.	M	P	P	P
	Hanson	Calcic Cryoboroll	loamy-skeletal, carbonatic				6.5-8.5		n.g.				
3-4	Mucet	Lithic Cryoboroll	loamy-mixed	Lewis & Clark						M	P	P	P
	Castner	Lithic Haploboroll	loamy-skeletal, mixed		50-70	6-20	7.2-8.4		n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
4-1	Craddock	Andic Cryochrept	loamy-skeletal, mixed	Mineral		41-80	5.7-6.0	L	tim	M	P	P	P
	Prexel	Udic Ustochrept	loamy-skeletal, mixed, frigid										
4-2	Sipple	Udic Argiboroll	fine-loamy, mixed	Fergus		>40			cult	M	P	P	P
	Raynesford	Calcic cryoboroll	fine-loamy, carbonatic		10-40	>60	7.9-8.6	L	n.g.				
	Little Horn	Argic Cryoboroll	fine, montmorillonitic			20-40	7.4-8.4	M	n.g.				
4-3	Tridell	Aridic Calciboroll	loamy-skeletal, mixed	Park						M	P	P	P
	Castner	Lithic Haploboroll	loamy-skeletal, mixed		50-70	6-20	7.2-8.4		n.g.				
	Harlem	Ustic Torrifluvent	fine, mont., frigid				7.9-8.7		cult				
	Whitore	Typic Cryochrept	loamy-skeletal carbonatic		25-50	< 40			f				
4-4	Bigell	Argic Cryoboroll	loamy-skeletal, mixed	Gallatin						M	P	P	P
	Hobacker	Pachic Cryoboroll	loamy-skeletal, mixed										

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
4-4 cont.	Garlet	Typic Cryochrept	loamy-skeletal, mixed			60-80	6.0-6.7		f				
5-1	Teton	Typic Cryoboroll	fine-loamy, mixed	Ravalli	2-30	24-40	6.0-7.3	L	cult.	S	F-G	P	F-P
	Holloway	Andic Cryochrept	loamy-skeletal, mixed		50-80		4.5-6.4		f				
	Blackleed	Typic Cryochrept	loamy-skeletal, mixed		20-35		6.6-7.0		R				
	Totelake	Andic Ustochrept	loamy-skeletal, mixed		35-70		6.2-6.6		n.g.				
5-2	Holloway	Andic Chryochrept	loamy-skeletal, mixed	Deerlodge, Flathead & Powell	50-80		4.5-6.4		f	S	F-G	P	F-P
	Duncom	Lithic Cryoboroll	loamy-mixed				8.0-8.4	L	R				
	Alpine								f				
5-3	Duncom	Lithic Cryoboroll	loamy, mixed	Fergus			8.0-8.4	L	R	S	F-G	P	F-P
	Skaggs	Calcic Cryoboroll	loamy-skeletal, carbonatic				6.6-8.4	L	n.g.				
5-4	Alpine			Beaverton						S	F-G	P	F-P

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
Soils of the Foothills #1-4													
1-1	Raynesford	Calcic Cryoboroll	Fine-loamy, carbonatic	Teton	10-40	>60	7.9-8.6	L	n.g.	M	F	F	G
	Whitore	Typic Cryochrept	Loamy-skeletal, carbonatic		25-50	<40			f				
1-2	Judith	Typic Calciboroll	fine-loamy, carbonatic	Judith Basin	35-50	>60	7.9-9.0	M	cult	M	F	F	G
	Ashuelot	Petrocalcic Calciboroll	loamy, carbonatic, shallow		5-35	<40	7.4-8.4	L	cult				
1-3	Castner	Lithic Haploboroll	loamy-skeletal, mixed	Lewis & Clark	50-70	6-20	7.2-8.4		n.g.	M	F	F	G
	Mucet	Lithic Cryoboroll	loamy, mixed										
	Whitore	Typic Cryochrept	loamy-skeletal, carbonatic		25-50	<40			f	M	F	F	G
1-4				Meagher						M	F	F	G
1-5				Meagher						M	F	F	G

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-6				Meagher						M	F	F	G
1-7				Meagher						M	F	F	G
1-8	Sweetgrass	Typic Argiboroll	clayey over sandy skeletal, montmorillonitic	Park					n.g.	M	F	F	G
1-9	Bridger	Argic Cryoboroll	fine, mixed	Park	5-30		6.6-8.4	L	n.g.	M	F	F	G
1-10	Tropal	Lithic Cryochrept	loamy-skeletal, carbonatic	Broadwater	35-60	12-20	8.2-8.4		R	M	F	F	G
	Rencot	Borollic lithic Calciboroll	loamy-skeletal, carbonatic		10-30	10-20	8.2-8.4		R				
	Tolman	Lithic Argiboroll	loamy-skeletal, mixed		35-75	10-20	6.4-6.8		n.g.				
1-11	Rivra	Ustic Torrifluvent	sandy-skeletal, mixed	Park	60-80		8.0-8.2		past	M	F	F	G
	Kiwanas	Typic Ustifluvent	coarse-loamy, mixed										
	Tridell	Aridic Calciboroll	loamy-skeletal, mixed										

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-12	Big Timber	Entic Happloboroll	clayey, mixed shallow	Park		6-20	7.4-7.8	L	n.g.	M	F	F	G
	Castner	Lithic Haploboroll	loamy-skeletal, mixed		50-70	6-20	7.2-8.4		n.g.				
	Ethridge	Aridic Argiboroll	fine, montmorillonitic			> 54	7.0-8.4		cult.				
1-13				Park						M	F	F	G
1-14	Merino	Lithic Cryorthents	loamy-skeletal, mixed, non-acid		35-90	10-20	6.6-6.8		n.g.	M	G	F	G
	Woodhurst	Argic Pachic Cryoboroll	loamy-skeletal, mixed		10-40	20-40	7.6-8.3	L	n.g.				
2-1	Sappington	Aridic Argiboroll	coarse-loamy, mixed	Broadwater	5-30		7.6-8.6		cult.	M	G	G	G
	Martinsdale	Typic Argiboroll	fine-loamy, mixed				7.0-8.8		cult.				
2-2	Passcreek	Argic Cryoboroll	fine-loamy, mixed	Broadwater						M	G	G	G
	Bridger	Argic Cryoboroll	fine, mixed		5-30		6.6-8.4	L					

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
2-3	Musselshell	Borollic Calciorthid	coarse-loamy, carbonatic	Broadwater	20-40		8.0-8.3		R	M	G	G	G
	Crago	Borollic Calciorthid	loamy-skeletal, carbonatic			>60	8.0-8.8		n.g.				
2-4	Abor	Borollic Ustic Camborthid	fine, montmorillonitic	Broadwater		20-40	7.8-8.6		cult.	M	G	G	G
	Cabbart	Ustic Torriorthent	loamy, mixed frigid,shallow			10-20	8.4-8.8		n.g.				
	Delphill	Ustic Torriorthent	fine-loamy, mixed, calcareous			20-40	8.0-8.8		n.R.				
2-5	Sappington	Aridic Argiboroll	coarse-loamy, mixed	Jefferson	5-30		7.6-8.6		cult.	M	G	G	G
	Roy	Typic Argiboroll	loamy-skeletal, mixed		35-80		6.8-7.8		n.R.				
	Oro Fino	Argic Cryoboroll	fine-loamy, mixed		10-40		5.2-8.2		n.g.				
2-6	Mord	Boralfic Cryoboroll	fine, montmorillonitic	Cascade			6.6-6.8		n.g.	M	G	G	G
	Loggert	Cryic Paleboroll	loamy-skeletal, mixed		50-80		5.8-6.4		n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
2-6 cont	Tigeron	Typic Cryoboralf	loamy-skeletal, mixed			>60	5.2-5.6		f				
2-7	Binna	Aridic Calciboroll	coarse-loamy, mixed	Park	5-30	>60	8.2-8.8		cult.	M	G	G	G
	Savage	Typic Argiboroll	fine, montmorillonitic		0-15		7.4-9.0	M-H	n.g.				
2-8	Tridell	Aridic Calciboroll	loamy-skeletal, mixed	Madison						M	G	G	G
	Evanston	Aridic Argiboroll	fine-loamy, mixed										
2-9	Hanson	Calcic Cryoboroll	loamy-skeletal, carbonatic	Cascade			6.5-8.5		n.g.	M	F	G	G
	Skaggs	Calcic Cryoboroll	loamy-skeletal, carbonatic				6.6-8.4	L	n.g.				
	Duncom	Lithic Cryoboroll	loamy, mixed				8.0-8.4	L	R				
2-10	Maurice	Typic Cryoboroll	loamy-skeletal, mixed	Stillwater Sweetgrass		20-40	7.2-7.8		n.R.	M	F	G	G
	Bearmouth	Typic Cryoboroll	sandy-skeletal, mixed				6.8-7.2		n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
2-11	Manhattan	Typic Calciboroll	coarse-loamy, mixed	Gallatin			8.4-9.1		cult.	M	F	G	G
	Bozeman	Argic Pachic Cryoboroll	fine-silty, mixed		0-15		7.0-8.8		past.				
	Bridger	Argic cryoboroll	fine, mixed		5-30		6.6-8.4	L	n.g.				
2-12	Phillipsburg	Argic Cryoboroll	fine-loamy, mixed	Granite & Sanders	0-40		6.4-8.2		n.R.	M	P	P	G
	Macetta	Pachic Cryoboroll	loamy-skeletal, mixed		20-50		7.0-7.2		n.g.				
	Cheadle	Lithic Cryoboroll	loamy-skeletal, mixed			<20	7.4-8.4	L	n.g.				
2-13	Crow	Typic Eutroboralf	very fine- mixed	Missoula & Mineral	15-50				tim	M	P	P	G
	Tarkio	Typic Eutroboralf	fine, mixed				6.1-7.9		n.g.				
2-14	Nagos	Typic Argiboroll	fine, mixed	Lake						M	P	P	G
	Lambert	Typic Ustorthents	fine-silty, mixed, calcareous			>60	7.9-8.4	L	n.g.				
	Post	Typic Natriboroll	very fine, mixed				6.5-8.5		n.R.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
2-15	McDonald	Boralfic Udic Argiboroll	fine, mixed	Lake & Sanders	5-40		6.6-8.5		past.	M	F	F	F
	Post	Typic Natriboroll	very fine, mixed				6.5-8.5		n.R.				
	Depew	Typic Eutroboralf	fine, mixed				8.0-8.5						
2-16										M	G	P	G
3-1	Roundbutte	Boroolic Natriargid	fine-silty, mixed	Park						M	G	P	G
	Regent	Typic Argiboroll	fine, montmorillonitic			30-40	7.0-8.2		cult.				
	Chama	Typic Haploboroll	fine-silty, mixed			> 60	7.0-8.4	L	cult.				
	Castner	Lithic Haploboroll	loamy-skeletal, mixed		50-70	6-20	7.2-8.4		n.g.				
4-1	Big Timber	Entic Haploboroll	clayey, mixed shallow	Powell		6-20	7.4-7.8	L	n.g.	M	G	P	G
	Cabba	Typic Ustorthent	loamy-mixed, frigid			< 20	7.9-8.4	L	n.g.				
4-2	Donald	Boralfic Cryoboroll	fine, montmorillonitic	Powell			6.1-8.2		n.R.	M	G	F	G

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
4-2 cont	Bridger	Argic Cryoboroll	fine, mixed		5-30		6.6-8.4	L	n.g.				
	Phillipsburg	Argic Cryoboroll	fine-loamy, mixed		0-40		6.4-8.2		n.R.				
4-3				Granite						M	G	F	G

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
Soils of the Plains #1-6													
1-1	Danvers	Typic Argiboroll	fine, montmorillonitic	Wheatland		>60	6.6-8.4	M-H	n.g.	M	G	G	G
	Judith	Typic Calciboroll	fine-loamy, carbonatic		35-50	>60	7.9-9.0	M	cult.				
	Reeder	Typic Argiboroll	fine-loamy, mixed			30-40	7.6-8.3		cult.				
1-2	Winifred	Typic Haploboroll	fine, montmorillonitic	Fergus		20-40	7.4-8.5	M		M	G	G	G
	Utica	Typic Calciboroll	sandy-skeletal, carbonatic		5-70	<40	8.4-8.6	L	n.g.				
	Marias	Ustic Torriorthent	fine, mont., calc., frigid				7.8-8.4	H	cult. &n.g.				
1-3	Dimyaw	Typic Ustorthent	fine, mont., calc., frigid	Wheatland			7.8-8.4		n.g.	M	G	G	G
	Wayden	Typic Ustorthent	clayey, mont., calc.,frigid,shal			10-20	7.2-8.2		n.g.				
	Castner	Lithic Haploboroll	Loamy-skeletal, mixed		50-70	6-20	7.2-8.4		n.g.				
1-4	Tanna	Andic Argiboroll	fine, montmorillonitic	Cascade		30-40	7.2-8.4		cult.	M	G	G	G
	Cabbart	Ustic Torriorthent	loamy, mixed, calc., frigid			10-20	8.4-8.8		n.g.				
	Straw	Cumulic Haploboroll	fine-loamy, mixed				7.6-8.4	L	n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
1-5	Rothiemay	Aridic Calciboroll	fine-loamy, mixed	Teton		> 60	8.0-8.4		past.	M	G	G	G
	Binna	Aridic Calciboroll	coarse-loamy, mixed		5-30	> 60	8.2-8.8		cult.				
1-6	Yawdim	Ustic Torriorthent	clayey, mixed, calc., shallow	Golden Valley		4-20	8.0-8.8		n.g.	M	G	G	G
	Rentsac	Lithic Ustic Torriorthent	loamy-skeletal, mixed, calc.		50-70	4-20	8.0-8.5		n.g.				
1-7	Musselshell	Borollic Calciorthid	loamy-skeletal, carbonatic	Musselshell	20-40		8.0-8.3		n.R.	M	G	G	G
	Yawdim	Ustic Torriorthent	clayey, mixed, calc., shallow			4-20	8.0-8.8		n.g.				
1-8	Musselshell	Borollic Calciorthid	loamy-skeletal, carbonatic	Golden Valley Wheatland	20-40		8.0-8.3		n.R.	M	G	G	G
	Crago	Borollic Calciorthid	coarse-loamy, carbonatic			> 60	8.0-8.8		n.g.				
	Cargill	Borollic Calciorthid	fine-silty, mixed			30-40	8.3-8.8		cult.				
1-9	Scorggim	Ustic Torriorthent	fine-silty, mixed calc., frigid	Musselshell		24-30	8.4-8.9		n.g.	M	G	G	G
	Lone Pine	Borollic Camborthid	fine-silty, mixed				7.0-8.8		past.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations	Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
1-10	Cushman	Ustollic Haplargids	fine-loamy, mixed, mesic	Yellowstone		20-40	6.6-8.4	M	n.g.	M	G	G	G
	Bainville	Ustic Torriorthent	fine-silty, mixed,mesic., calc.			20-40	7.9-9.0	L					
1-11	Alder	Udic Argiboroll	fine, mixed	Cascade		20-40	5.6-7.3	L		M	G	G	G
	Sinnigam	Lithic Argiboroll	clayey-skeletal, mixed			10-20	6.4-7.3		n.g.				
	Adel	Pachic Cryoboroll	fine-loamy, mixed		5-10		5.6-7.3	L					
1-12	Savage	Typic Argiboroll	fine, montmorillonitic	Judith Basin	0-15		7.4-9.0	M-H	n.g.	M	G	G	G
	Straw	Cumulic Haploboroll	fine-loamy, mixed				7.6-8.4	L	n.g.				
1-13	Fergus	Typic Argiboroll	fine, mixed	Cascade		> 60	6.6-8.4	M	cult.	M	G	G	G
	Twin Creek	Typic Haploboroll	fine-loamy, mixed			> 60	6.6-8.4	M	cult.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
1-14	Trulon	Typic Calciboroll	fine-loamy, carbonatic	Cascade		20-40	7.6-8.8		cult.	M	G	G	G
	Lap	Lithic Calciboroll	loamy-skeletal, carbonatic		50-70	10-20	7.4-9.0		R				
	Bitton	Entic Haploboroll	loamy-skeletal, mixed		0-15	> 50	7.8-8.8		n.g.				
1-15	Tetull	Typic Ustipsamment	mixed, frigid	Cascade						M	G	G	G
	Lihen	Entic Haploboroll	sandy-mixed										
	Korchea	Typic Ustfluvent	fine-loamy, mixed,calc., frigid				8.0-8.2		cult.				
1-16	Teton	Typic Cryoboroll	fine-loamy, mixed	Judith Basin	2-30	24-40	6.0-7.3	L	cult.	M	G	G	G
	Cheadle	Lithic Cryoboroll	loamy-skeletal, mixed			< 20	7.4-8.4	L	n.g.				
1-17	Heldt	Ustic Camborthid	fine-loamy	Carbon		> 60	7.9-8.4	M	n.g.	M	G	G	G
	Fort Collins	Ustollic Haplargids	fine-loamy										

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
1-18	Danvers	Typic Argiboroll	fine-montmorillonitic	Yellowstone		>60	6.6-8.4	M-H	n.g.	M	G	G	G
	Windham	Typic Calciboroll	loamy-skeletal, carbonatic		10-15				cult.				
1-19	Cargill	Botollic Calciborthid	fine-silty, mixed	Teton		30-40	8.3-8.8		cult.	M	G	G	G
	Abor	Borollic Camborthid	fine-montmorillonitic			20-40	7.8-8.6		cult.				
1-20	Vanda	Ustic Torriorthent	fine, mont., calc., mesic	Rosebud		> 60	8.0-9.2	H	n.R.	M	G	G	G
	Lisam	Ustic Torriorthent	clayey, mont., nonacid, frigid			10-20	7.0-8.4		n.g.				
1-21	Terry	Ustollic Haplargids	coarse-loamy, mixed, mesic	Rosebud	0-15	20-40	7.0-8.4	L	n.g.	M	G	G	G
	Olney	Ustollic Haplargids	fine-loamy, mixed, mesic		0-15		7.2-8.2		n.R.				
2-1	Tullock	Pachic Arqiustoll	fine, mixed, mesic	Fergus						S	G	F	G
	Martinsdale	Typic Argiboroll	fine-loamy, mixed				7.0-8.8		cult				
	Maginnis	Lithic Haploboroll	clayey, skeletal mixed		50-90	4-15	6.1-6.5	L	n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-2	Fairfield	Typic Argiboroll	fine-loamy, mixed	Teton		>60	7.4-8.5	L	cult	S	G	F	G
	Cabba	Typic Ustorthent	loamy, mixed, calc., frigid, shallow			<20	7.9-8.4		n.g.				
	Utica	Typic Calciboroll	sandy-skeletal, mixed, carbonatic		5-70	<40	8.4-8.6	L	n.g.				
2-3	Reeder	Typic Argiboroll	fine-loamy, mixed	Wheatland		30-40	7.6-8.3		cult	S	G	F	G
	Regent	Typic Argiboroll	fine, montmorillonitic			30-40	7.0-8.2		cult				
	Wayden	Typic Ustorthent	clayey, mont., calc., frigid			10-20	7.2-8.2		n.g.				
2-4	Winifred	Typic Haploboroll	fine-loamy, mixed	Cascade		20-40	7.4-8.5	M		S	G	F	G
	Yawdim	Ustic Torriorthent	clayey, mixed, frigid, shallow			4-20	8.0-8.4		n.g.				
2-5	Lisam	Ustic Torriorthent	clayey, mont., nonacid, frigid	Golden Valley		10-20	7.0-8.4		n.g.	S	G	F	G
	Yawdim	Ustic Torriorthent	clayey, mixed, frigid, shallow			4-20	8.0-8.4		n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-6	Kremlin	Aridic Argiboroll	fine-loamy, mixed	Teton						S	G	F	G
	Abor	Borollic Camborthid	fine, montmorillonitic			20-40	7.8-8.6		cult				
2-7	Lepley	Natric Camborthid	fine, mont., frigid	Cascade						S	G	F	G
	Benz	Ustic Torrifluvent	fine-loamy, mixed, calc.			>60	8.8-9.6		n.g.				
	Marias	Ustic Torriorthent	fine, mont., calc., frigid				7.8-8.4	H	cult & n.g.				
2-8	Absher	Borollic Natargid	fine, montmorillonitic	Cascade		>60	6.6-8.5		n.g.	S	G	F	G
	Nobe	Ustic Torriorthent	fine, mont., calc.,frigid			>60	8.0-9.0		n.g.				
	Lone Pine	Borollic Camborthid	fine-silty, mixed				7.0-8.8		past				
2-9	Marias	Ustic Torriorthent	fine, mont., calc.,frigid	Cascade			7.8-8.4	H	cult & n.g.	S	G	F	G
	Kobar	Ustic Torriorthent	fine, mont., calc.,frigid				8.0-8.4		cult				
	Abor	Borollic Camborthid	fine, montmorillonitic			20-40	7.8-8.6		cult				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-10	Wormser	Aridic Argiustoll	fine, mont., mesic	Stillwater		20-40	6.6-8.4	M	n.g.	S	G	F	G
2-11	Baineville	Ustic Torriorthent	fine-silty, mixed, calc.			20-40	7.9-9.0	L		S	G	F	G
2-12	Work	Typic Argiboroll	fine, montmorillonitic	Lewis & Clark		>40	6.6-8.4	M	n.g.	S	G	F	G
	Arny	Pachic Udic Argiboroll	fine-loamy, mixed				6.5-8.5						
2-13	Savage	Typic Argiboroll	fine, montmorillonitic	Park	0-15		7.4-9.0	M-H	n.g.	S	G	F	G
2-14	Alder	Udic Argiboroll	fine, mixed	Chouteau		20-40	5.6-7.3	L		S	G	F	G
	Eltsac	Vertic Ustorthent	very fine, mont., calc., frigid			24-32	7.4-8.4		cult				
	Tigeron	Typic Cryoboralf	loamy-skeletal, mixed			>60	5.2-5.6		f				
2-15	Danvers	Typic Argiboroll	fine, montmorilloritic	Fergus		>60	6.6-8.4	M-H	n.g.	S	G	F	G
	Judith	Typic Calciboroll	fine-loamy, carbonatic		35-50	>60	7.9-9.0	M	cult				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-16	Absarokee	Typic Argiboroll	fine, montmorillonitic	Judith Basin		20-40	7.4-8.0	M.	n.g.	S	G	F	G
	Maginnis	Lithic Haploboroll	clayey-skeletal, mont.		50-90	4-15	6.1-6.5	L	n.g.				
2-17	Terrad	Typic Argiboroll	fine, mixed	Judith Basin			6.1-8.4	H		S	G	F	G
	Tumberg	Typic Haploboroll	fine, mixed										
	Big Timber	Entic Haploboroll	clayey, mixed, shallow			6-20	7.4-7.8	L	n.g.				
2-18	Castner	Lithic Haploboroll	loamy-skeletal, mixed	Wheatland	50-70	6-20	7.2-8.4		n.g.	S	G	F	G
	Darret	Typic Argiboroll	fine, mixed				7.4-8.2	L	n.g.				
	Fergus	Typic Argiboroll	fine, mixed			>60	6.6-8.4	M	cult				
2-19	Tanna	Aridic Argiboroll	fine, montmorillonitic	Sweetgrass		30-40	7.2-8.4		cult	S	G	F	G
	Rentsac	Lithic Ustic Torriorthent	loamy-skeletal, mixed, calc.	Stillwater	50-70	4-20	8.0-8.5		n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-20	Cabbart	Ustic Torriorthent	clayey, mixed, calc., shallow	Cascade		10-20	8.4-8.8		n.g.	S	G	F	G
	Rentsac	Lithic Ustic Torriorthent	loamy-skeletal, mixed, calc.		50-70	4-20	8.0-8.5		n.g.				
	Havre	Ustic Torrifluvent	fine-loamy, mixed, calc., frigid				8.2-8.6	M-L	cult				
2-21				Meagher						S	G	F	G
2-22				Meagher						S	G	F	G
2-23	Bridger	Argic Cryoboroll	fine, mixed	Park	5-30		6.6-8.4	L		S	G	F	G
2-24	Vananda	Ustic Torriorthent	fine, mont., calc., mesic	Yellowstone		>60	8.0-8.8		n.g.	S	G	F	G
	McKenzie	Typic Haplaquepts	fine, mont., calc., frigid			>60	7.9-9.5	H	n.g.				
	Arvada	Ustollic Natargids	fine, mont.		<5	>60	7.9-9.2	L-M					

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-25	Maginnis	Lithic Haploboroll	clayey-skeletal, mixed	Yellowstone	50-90	4-15	6.1-6.5	L	n.g.	S	G	F	G
	Absarokee	Typic Argiboroll	fine, montmorillonitic			20-40	5.6-7.3	L					
2-26	Lambeth	Ustic Torriorthent	fine-silty, mixed, mesic	Rosebud			8.0-8.4		n.g.	S	G	F	G
	Yamac	Borollic Camborthid	fine-loamy, mixed										
2-27	Thebo	Ustertic Torriorthent	fine, mont., calc., frigid	Fergus		20-40	7.6-8.0		n.g.	S	G	F	G
	Lisam	Ustic Torriorthent	clayey, mont., nonacid, frigid			10-20	7.0-8.4		n.g.				
2-28	Thedalund	Ustic Torriorthent	fine-loamy, mixed, calc.	Rosebud & Big Horn	0-15		8.0-8.4		n.g.	S	G	F	G
	Midway	Ustic Torriorthent	clayey, calc., mesic, shallow			10-20	7.9-8.4	H	n.g.				
2-29	Nelson	Ustic Torriorthent	clayey, mixed, shallow	Treasure & Big Horn	<10	20-40	8.2-8.4		cult	S	G	F	G
	Alice	Aridic Argiustoll	fine-loamy, mixed										

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
2-30	Vananda	Ustic Torriorthent	fine, mont., calc., mesic	Treasure		>60	8.0-8.8		n.g.	S	G	F	G
3-1	Lismas	Ustic Torriorthent	clayey, calc., mesic, shallow	Rosebud		10-20	7.4-8.4	H	n.g.	S	G	P	F
	Thebo	Ustertic Torriorthent	fine, mont., calc., mesic			20-40	7.6-8.0		n.g.				
	Lisam	Ustic Torriorthent	clayey, mont., nonacid, frigid			10-20	7.0-8.4		n.g.				
3-2	Absher-Badlands	Borollic Natargids	fine, montmorillonitic	Teton		>60	6.6-8.5		n.g.	S	G	P	F
4-1	Fairfield	Typic Argiboroll	fine-loamy, mixed	Chouteau		>60	7.4-8.5		cult	M	F	G	G
	Ashuelot	Petrocalcic Calciboroll	loamy, carbonatic, shallow			5-35	<40	7.4-8.4	L				
	Cabba	Typic Ustorthent	loamy, mixed, frigid, shallow, calc.			<20	7.9-8.4	L	n.g.				
4-2	Bearpaw	Typic Argiboroll	fine, montmorillonitic	Chouteau	< 5		6.6-7.2			M	F	G	G
	Williams	Typic Argiboroll	fine-loamy, mixed		1-8				cult				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
4-2 cont.	Zahl	Entic Haploboroll	fine-loamy, mixed		1-10		8.0-8.4		n.g.				
4-3	Dutton	Ustertic Argiboroll	fine, montmorillonitic	Cascade		30-40	7.2-8.9		cult	M	F	G	G
	Pylon	Typic Eutroboralf	fine, montmorillonitic			<40	7.0-8.9		cult				
4-4	Linnet	Ustertic Argiboroll	fine, montmorillonitic	Cascade			7.2-8.8		cult	M	F	G	G
	Acel	Mollic Eutroboralf	fine, montmorillonitic		< 5		6.8=8.8		cult				
	Marias	Ustertic Torriorthent	fine, mont., calc., frigid				7.8-8.4	H	cult& n.g.				
4-5	Gerber	Vertic Argiboroll	fine, montmorillonitic	Cascade			7.0-8.2		cult	M	F	G	G
	Shaak	Abruptic Argiboroll	fine, montmorillonitic			> 60	6.6-8.4	H	n.g.				
4-6	Duffy	Typic Haploboroll	fine, loamy, mixed	Cascade			7.2-8.4			M	F	G	G
	Lihen	Entic Haploboroll	sandy-mixed										
	Tally	Typic Haploboroll	coarse-loamy, mixed										

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
4-7	Assinoboine	Aridic Argiboroll	fine, montmorillonitic	Chouteau		>40	6.4-7.0			M	F	G	G
	Evanston	Aridic Argiboroll	fine-loamy, mixed										
	Chinook	Aridic Haploboroll	coarse-loamy, mixed				> 60		cult				
4-8	Scobey	Aridic Argiboroll	fine, montmorillonitic		5-20		6.5-8.3		cult	M	F	G	G
	Kevin	Aridic Argiboroll	fine-loamy, mixed				7.8-8.6		cult				
4-9	Scobey	Aridic Argiboroll	fine, montmorillonitic	Teton & Chouteau	5-20		6.5-8.3		cult.	M	F	G	G
	Kevin	Aridic Argiboroll	fine-loamy, mixed				7.8-8.6		cult.				
	Phillips	Borollic Paleoargid	fine, montmorillonitic				6.1-8.5		n.g.				
4-10	Kobar	Borollic Camborthid	fine, montmorillonitic	Cascade			8.0-8.4		cult	M	F	G	G
	Ethridge	Aridic Argiboroll	fine, montmorillonitic			>54	7.0-8.6		cult				
	Lambeth	Ustic Torriorthent	fine-silty, mixed, frigid				8.0-8.4		n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
4-11	Pendroy	Ustertic Torriorthent	very-fine, mont. mesic	Cascade & Chouteau			7.8-8.2		n.g.	M	F	G	G
	Marias	Ustertic Torriorthent	fine, mont., calc., frigid				7.8-8.4	H	cult& n.g.				
	Scobey	Aridic Argiboroll	fine, montmorillonitic		5-20		6.5-8.3		cult				
	Kiev	Typic Calciboroll	fine-loamy, mixed				7.4-8.2		n.g.				
4-12	Ashuelot	Petrocalcic Calciboroll	loamy, carbonatic, shallow	Lewis & Clark	5-35	<40	7.4-8.4	L		M	F	G	G
5-1	Beaverton	Typic Argiboroll	loamy-skeletal, mixed	Stillwater & Carbon		20-30	6.5-8.5	L		S			
	Heath	Argic Cryoboroll	fine, montmorillonitic		0-35		7.4-8.2		n.g.				
	Charlo	Argic Cryoboroll	sandy-skeletal, mixed		2-30	20-40	6.0-6.5		n.g.				
5-2	Martinsdale	Typic Argiboroll	fine-loamy, mixed	Sweetgrass			7.0-8.8			S			
	Hilger	Typic Argiboroll	clayey-skeletal, mixed			35-81	7.8-8.2		n.R.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
5-3	Martinsdale	Typic Argiboroll	fine-loamy, mixed	Wheatland			7.0-8.8			S			
	Danvers	Typic Argiboroll	fine, montmorillonitic			>60	6.6-8.4	M-H	n.g.				
	Utica	Typic Calciboroll	sandy-skeletal, carbonatic		5-70	∠40	8.4-8.6	L	n.g.				
5-4	Wayden	Typic Ustorthent	clayey, mont., calc., frigid	Sweetgrass & Golden Valley		10-20	7.2-8.2		n.g.	S			
	Castner	Lithic Haploboroll	fine-skeletal, mixed		50-70	6-20	7.2-8.4		n.g.				
5-5	Wanetta	Ustollic Haplargids	sandy-skeletal, mixed, mesic	Stillwater	0-30	>60	7.4-8.4	M	n.R.	S			
	Kyle	Ustertic camborthid	very-fine, mont., mesic			40-60	7.4-9.0	H	n.g.				
5-6	Midway	Ustic torriorthent	clayey, calc., frigid, shallow	Stillwater & Yellowstone		10-20	7.9-8.4	H	n.g.	S			
	Heldt	Ustertic Camborthid	fine, mont., mesic			> 60	7.9-8.4	M	n.g.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
5-7	Thedalund	Ustic Torriorthent	fine-loamy, mixed, mesic, calc.	Yellowstone& Musselshell	0-15		8.0-8.4		n.g.	S			
	Travesilla	Lithic Ustic Torriorthent	loamy, mixed, mesic, calc.		0-35	10-20	6.6-7.3	L	n.R.				
5-8	Worland	Typic Torriorthent	coarse-loamy, mixed, calc., mesic	Yellowstone	0-15	20-40	7.6-8.3	L		S			
	Baineville	Ustic Torriorthent	fine-silty, mixed, mesic., calc.			20-40	7.9-9.0	L					
	Travesilla	Lithic Ustic Torriorthent	loamy, mixed, calc., mesic		0-35	10-20	6.6-7.3	L	n.R.				
5-9	Badlands			Fergus & Chouteau						S			
	Absarokee	Typic Argiboroll	fine, montmorillonitic	Stillwater		20-40	7.4-8.0	M	n.g.				
	Sinnigam	Lithic Argiboroll	clayey-skeletal mixed			10-20	6.4-7.3		n.g.				
5-10	Reeder	Typic Argiboroll	fine-loamy, mixed	Judith Basin		30-40	7.6-8.3		cult.				
	Regent	Typic Argiboroll	fine, montmorillonitic			30-40	7.0-8.2		cult.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters						Impact Interpretations			
												Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
5-11	Norbert	Typic Ustorthent	clayey, calc., frigid, shallow	Fergus		4-20	8.3-8.8		n.g.	S			
	Cabba	Typic Ustorthent	loamy, mixed, calc., frigid			< 20	7.9-8.4	L	n.g.				
5-12	Boxwell	Aridic Haploboroll	fine-loamy, mixed	Fergus			7.0-8.5		cult.	S			
	Tanna	Aridic Argiboroll	fine, montmorillonitic			30-40	7.2-8.4		cult.				
5-13	Midway	Ustic Torriorthent	clayey, calc., frigid, shallow	Musselshell		10-20	7.9-8.4	H	n.g.	S			
	Baineville	Ustic Torriorthent	fine-silty, mixed, calc., mesic			20-40	7.9-9.0	L					
5-14	Midway	Ustic Torriorthent	clayey, calc., frigid, shallow	Carbon		10-20	7.9-8.4	H	cult.	S			
	Travesilla	Lithic Ustic Torriorthent	loamy- skeletal, calc., mixed		0-35	10-20	6.4-6.8	L	N.R.				
5-15	Pierre	Ustertic Camborthid	very-fine, mont., mesic	Yellowstone & Big Horn		20-40	7.9-8.4	H		S			
	Lismas	Ustic Torriorthent	clayey, calc., frigid, shallow			10-20	7.4-8.4	H	n.g.				
5-16	Mcrae	Ustollic Camborthid	fine-loamy, mixed, mesic	Yellowstone		48-76	7.9-8.4	L	cult.	S			
	Keiser	Ustollic Haplargid	fine-silty, mixed, mesic			> 60	7.9-9.0	H	cult.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
5-17	Wanetta	Ustollic Haplargid	fine-loamy, skeletal, mixed	Yellowstone		> 60	6.5-8.5	M	n.g.	S			
	Marias	Ustertic Torriorthent	fine, mont., calc., frigid	Wheatland			7.8-8.4	H	cult. n.g.				
5-18	Thebo	Ustertic Torriorthent	fine, mont., calc., mesic			20-40	7.6-8.0		n.g.	S			
	Lisam	Ustic Torriorthent	clayey, calc., frigid, shallow			10-20	7.0-8.4		n.g.				
5-19	Wayden	Typic Ustorthent	clayey, calc., frigid, shallow	Rosebud & Big Horn		10-20	7.2-8.2		n.g.	S			
	Regent	Typic Argiboroll	fine, montmorillonitic			30-40	7.0-8.2		cult.				
5-20	Ringling	Typic Haploboroll	fragmental, mixed	Big Horn & Rosebud	30-80	5-20	7.4-8.4	L	n.g.	S			
	Searing	Typic Haploboroll	fine-loamy mixed			20-40	7.6-8.4		cult.				
5-21	Wibaux	Ustic Torriorthent	loamy, skeletal, nonacid, mesic	Rosebud			7.6-8.4	L		S			
5-22	Thedalund	Ustic Torriorthent	fine-loamy, mixed, mesic		0-15		8.0-8.4		n.g.	S			

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundation	Access Roads	Right of Way
5-22 (cont)	Spearman	Aridic Haplustoll	fine-loamy, fragmental, mixed		0-35	20-40	7.6-8.2		n.g.	S			
6-1	Hogbacks			Musselshell						S			

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
Soils of the Basins #1-2													
1-1	Sappington	Aridic Argiboroll	fine-silty, mixed, frigid	Lewis & Clark	5-30		7.6-8.6		cult	S	G	G	G
	Amesha	Borollic Calciorthid	coarse-loamy, mixed		0-5	>40	8.0-8.4						
1-2	Amesha	Borollic Calciorthid	coarse-loamy, mixed	Broadwater	0-5	>40	8.0-8.4			S	G	G	G
	Brocko	Borollic Calciorthid	coarse-loamy, mixed				8.4-9.1		cult				
	Mussel	Ustic Torriorthent	fine-loamy, mixed, calcareous		0-30		8.0-8.2		cult				
1-3	Radersburg	Aridic Argiboroll	clayey-skeletal mixed	Broadwater	35-65		7.8-8.2		n.R.	S	G	G	G
	Hilger	Typic Argiboroll	clayey-skeletal, mixed		35-80		7.8-8.2		n.R.				
	Scravo	Borollic Calciorthid	sandy-skeletal, mixed		35-65		8.0-8.6		cult				
1-4	Chinook	Aridic Haploboroll	coarse-loamy, mixed	Broadwater		>60			cult	S	G	G	G
	Amesha	Borollic Calciorthid	coarse-loamy, mixed		0-5	>40	8.0-8.4						

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-5	Manhattan	Typic Calciboroll	coarse-loamy, mixed	Gallatin			8.4-9.1		cult	S	G	G	G
	Ashuelot	Petrocalcic Calciboroll	loamy, carbonatic, shallow		5-35	<40	7.4-8.4	L					
1-6	Radersburg	Aridic Argiboroll	fine-silty, mixed, frigid	Lewis & Clark	35-65		7.8-8.2		n.R.	S	G	G	G
	Parshall	Pachic Haploboroll	coarse-loamy, mixed										
	Alluvial												
1-7	Brownlee	Ustic Argixeroll	fine-loamy, mixed, mesic	Jefferson						S	G	G	G
	Richlie	Borollic Calciorthid	coarse-loamy, mixed			10-25	8.2-8.8		n.g.				
	Larimer	Ustollic Haplargids	fine-loamy, mixed, mesic										
1-8				Meagher						S	G	G	G
1-9				Meagher						S	G	G	G

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-10	Lamoure	Cumulic Haplaquolls	fine-silty, mixed, calc.	Park			7.3-8.4	M-L		S	G	G	G
	Gallatin	Pachic Cryoboroll	fine-loamy, mixed				7.3-8.4	L	cult.				
	Havre	Ustic Torrifluvent	fine-loamy, mixed, calc.				8.2-8.6	M-L	cult.				
1-11	Crago	Borollic Calciorthid	loamy-skeletal, carbonatic	Madison		>60	8.0-8.8		n.g.	S	G	G	G
	Amesha	Borollic Calciorthid	coarse-loamy, mixed		0-5	>40	8.0-8.4						
	Scravo	Borollic Calciorthid	sandy-skeletal, mixed		35-65		8.0-8.6		cult.				
1-12	Brocko	Borollic Calciorthid	coarse-silty, mixed	Madison			8.4-9.1		cult.	S	G	G	G
	Evanston	Aridic Argiboroll	fine-loamy, mixed										
1-13	Perma	Typic Haploboroll	loamy-skeletal, mixed	Lake & Sanders	15-40	20-40	6.6-7.2		n.g.	SL	G	F-G	G
	Krouse	Andic Ustochrept	sandy-skeletal, mixed, frigid										
	Lolo	Pachic Haploboroll	loamy-skeletal, mixed			>40	6.6-7.0		cult.				

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-14	Quigley	Typic Haploboroll	fine-loamy, mixed	Lake						SL	G	F-G	G
	Tally	Typic Haploboroll	coarse-loamy, mixed										
	Blanchard	Typic Ustipsamments	mixed, frigid			20-40	6.6-8.0		cult.				
1-15	Riverside	Entic Haploboroll	sandy-skeletal, mixed	Ravalli						SL	G	F-G	G
	Oro Fino	Argic Cryoboroll	fine-loamy, mixed		10-40		5.2-8.2						
	Lamoure	Cumulic Haplaquoll	fine-silty, mixed, calcareous				7.3-8.4	M-L					
1-16	Somers	Udic Haploboroll	fine-silty, mixed	Lake						S	P	F	G
	Kalispell	Udic Haploboroll	coarse-loamy, mixed										
1-17	Judith	Typic Calciboroll	fine-loamy, carbonatic	Powell, Lake & Deer Lodge	35-50	>60	7.9-9.0	M	cult	S	P	F	G
	Martinsdale	Typic Argiboroll	fine-loamy, mixed				7.0-8.8		cult				
2-1				Deer Lodge & Lewis & Clark						S	G	G	F

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
Soils of the Alluvial Lands (floodplains) #1-2													
1-1	Grantsdale	Typic Haploboroll	fine-loamy, mixed	Missoula & Deer Lodge			7.1-8.8		past	SL	F-G	F-G	F-G
	Clarkfork	Typic Ustorthent	sandy-skeletal, mixed				6.0-6.8		n.g.				
1-2	Havrelon	Typic Ustifluvent	fine-loamy, mixed, calc. frigid	Wheatland G. Valley		>60	7.4-8.4	M-H		SL	F-G	F-G	F-G
	Lohler	Typic Ustifluvent	fine, fine, mont. frigid				7.8-8.2		cult				
	Glenberg	Ustic Torrifluvent	coarse-loamy, mixed		0-50	>60	7.4-8.4	L					
1-3	Havrelon	Typic Ustifluvent	fine-loamy, mixed, frigid	Sweetgrass		>60	7.4-8.4	M-H		SL	F-G	F-G	F-G
	Farnuf	Typic Argiboroll	fine-loamy, mixed				7.4-8.5		n.g.				
	Dimmick	Vertic Haplaquolls	fine-mont. frigid				7.4-7.8	M					
1-4	Haverson	Ustic Torrifluvents	fine-loamy, mixed, calc., frigid	Yellowstone Rosebud	<5	>60	7.9-8.4	M-H		SL	F-G	F-G	F-G

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-4 cont	Lohmiller	Ustic Torrifluvent	fine, mont., mesic			>60	7.9-9.0	H	cult	SL	F-G	F-G	F-G
1-5	Harlem	Ustic Torrifluvent	fine, mont. calc.	Cascade			7.9-8.7		cult	SL	F-G	F-G	F-G
	Havre	Ustic Torrifluvent	fine-loamy, mixed, calc. frigid				8.2-8.6	M-L	cult				
1-6	Straw	Cumulic Haploboroll	fine-loamy, mixed	Cascade			7.6-8.4	L	n.g.	SL	F-G	F-G	F-G
	Tremble	Typic Ustfluvent	coarse-loamy, mixed				7.8-8.4		cult				
1-7	Yamac	Borollic Camborthid	fine-loamy, mixed	Cascade						SL	F-G	F-G	F-G
	Kobar	Borollic Camborthid	fine, mont.				8.0-8.4		cult				
	Rivra	Ustic Torrifluvent	sandy-skeletal, mixed, frigid		60-80		8.0-8.2		past				
1-8	Regan	Typic Calciaquoll	fine-silty, frigid	Lewis & Clark		30-40	7.0-8.2		cult	SL	F-G	F-G	F-G
	Vastine	Typic Haplaquolls	fine-loamy, frigid										

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-8 cont	Fairdale	Mollic Ustifluvent	fine-loamy, mixed		60-80	> 60	7.4-8.5		cult	SL	F-G	F-G	F-G
1-9	Havre	Ustic Torrifluvent	fine-loamy, mixed, frigid	Lewis & Clark			8.2-8.6	M-L	cult	SL	F-G	F-G	F-G
	Korchea	Typic Ustifluvent	fine-loamy, mixed, calc.				8.0-8.2		cult				
1-10	Villy	Typic Fluvaquent	fine-silty, mixed, calc.	Broadwater			8.0-8.4		past	SL	F-G	F-G	F-G
	Toston	Aquic Natrargids	fine-loamy, mixed, frigid				8.2-9.2		n.R				
	Rivra	Ustic Torrifluvent	sandy-skeletal, mixed, frigid				8.0-8.2		past				
1-11	Slocum	Aquic Cryoboroll	fine-loamy, mixed	Jefferson			5.1-5.5	L	n.g.	SL	F-G	F-G	F-G
	Bank	Typic Ustifluvent	sandy, mixed, frigid				7.8-8.5	L					
	Rauville	Mollic Fluvaquent	fine-silty, mixed, calc.										
1-12	Gallatin	Pachic Cryoboroll	fine-loamy, mixed	Gallatin			7.3-8.4	L	cult	SL	F-G	F-G	F-G

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
1-12 cont	Beaverton	Typic Argiboroll	loamy-skeletal, mixed			20-30	6.5-8.5	L					
	Manhattan	Typic Calciboroll	coarse-loamy, mixed				8.4-9.1		cult				
1-13	Bozeman	Argic Pachic Cryoboroll	fine-silty, mixed	Gallatin	0-15		7.0-8.8		past	SL	F-G	F-G	F-G
	Manhattan	Typic Calciboroll	coarse-loamy, mixed				8.4-9.1		cult				
	Millville	Typic Haploxeroll	coarse-silty, carbonatic										
1-14	Rivra	Ustic Torrifluvent	sandy-skeletal, mixed, frigid	Madison	60-80		8.0-8.2		past	SL	F-G	F-G	F-G
	Havre	Ustic Torrifluvent	fine-loamy, mixed,calcareous				8.2-8.6	M-L	cult				
	Villy	Typic fluvaquent	fine-silty, mixed,calcareous				8.0-8.4		cult				
1-15	Havre	Ustic Torrifluvent	fine-loamy mixed,calcareous	Rosebud			8.2-8.6	M-L	cult	SL	F-G	F-G	F-G
	Harlem	Ustic Torrifluvent	fine, mont., calc., mesic				7.9-8.7		cult				
1-16	Lohmiller	Ustic Torrifluvent	fine, mont. mesic	Big Horn		>60	7.9-9.0	H	cult	SL	F-G	F-G	F-G

TABLE 1 (Cont.)

Soil Taxonomy					Impact Parameters					Impact Interpretations			
											Suitability Ratings		
Series Unit #	Series	Subgroup	Textural Family	County	% Coarse Fragment	Depth to Bedrock	pH Fertility	Shrink/ Swell	Tilth	Erosion Hazard	Tower Foundations	Access Roads	Right of Way
2-1	Haverson	Ustic Torrifluvent	fine-loamy, mixed, frigid	Ravalli	5	>60	7.9-8.4	M-H		SL	F	P	F
	Victor	Typic Haploboroll	coarse-loamy, mixed				6.0-7.0						
	Cherette	Typic Ustochrept	sandy-skeletal, mixed						f				
	Blogett	Udic Haploboroll	sandy-skeletal, mixed				6.5-6.9		n.f.				
2-2	Straw	Cumulic Haploboroll	fine-loamy, mixed	Ravalli & Granite			6.6-8.4	L	n.g.	SL	F	P	F
	Gallatin	Pachic Cryoboroll	fine-loamy, mixed				7.3-8.4	L	cult				
	Slocum	Aquic Cryoboroll	fine-loamy, mixed				5.1-5.5		n.g.				

APPENDIX K: Geology

K1 Historic Geology

The basis for subsequent depositional and structural evolution of Montana was established with deposition of the Late Precambrian Belt Group, a thick sequence of strata deposited within a geosyncline which paralleled the present Western margin of North America, and within a large embayment which projected into the central part of Montana. The margins of Belt sedimentation included all of the Rocky Mountains portion of Montana with the exception of the southwest corner of the state, which covered by pre-Belt metamorphic rocks during Belt time, and was separated from the Belt sea on the north and west by major faults. One locality where the proximity of the Belt shoreline is apparent is in Jefferson Canyon, west of Three Forks, from which arkosic conglomerates of pre-Belt debris (LaHood Conglomerate) grade, over a few miles to the north, into finer grained, normal Belt sediments.

Belt strata, for the most part, include red, green, gray, and brown argillites, quartzites, and buff-weathering, black silty carbonates. They are characterized throughout by shallow water and mudflat features, gradational boundaries, and great uniformity of sediments through large sections of strata. These features imply unusual stability of environmental conditions over long periods of time.

Extensive erosion separates Precambrian rocks from those of the Paleozoic. Paleozoic geosynclinal sedimentation was superimposed on that of the Belt Group, and these strata also lap out onto the craton. Early and Late Paleozoic and Triassic times featured short intervals of marine invasion of Montana, alternating with periods of extensive erosion. Middle Paleozoic (Middle Devonion and Mississippian) shallow-sea carbonate deposition was widespread and continuous over the state.

Geosynclinal activity was terminated in Late Jurassic time, with initiation of Nevadan mountain building. The resulting land area extended along the western border of Montana, and was separated from the eastern portion of the continent by a wide seaway which was continuous from the present Arctic Ocean to the Gulf of Mexico. The waters of the seaway regressed and returned along this course a number of times during the Cretaceous, partly due to periodic, regional uplift or subsidence, and partly due to eustatic sea level changes. Most of the sediments of this period were derived from the land source to the west, Marine invasion alternated with intervals of continental sedimentation.

With deposition of the Late Cretaceous Bearpaw Shale, marine waters retreated from this part of North America for the final time. Near the beginning of the Cenozoic, roughly coincident with Elkhorn Mountain volcanism and initiation of Laramide overthrusting, deltaic sedimentation and coal swamps became widespread in basinal areas of eastern Montana.

Major thrust faulting in western Montana occurred during Middle Paleocene to Early Eocene (McMannis 1955). Soon afterward, block faulting (Pardee 1950) began to break up western Montana into isolated basins and uplands. The early basins were not interconnected by rivers, resulting in accumulation of sparse Eocene and, more widespread, Oligocene lake and terrestrial sediments. Much of the Tertiary sediment is volcanic debris from unknown specific sources. Additional sediments were derived locally, from the older rocks which formed the uplands surrounding the basins. By this time, much of the Paleozoic geosynclinal strata of western Montana had already been removed by erosion.

A middle Tertiary unconformity present in most or all of the western basins (Kuenzi 1966) may represent a time when the earlier-formed basins were filled to capacity, making possible pervasive drainage systems. Increase in faulting activity or other factors resulted in renewed Oligocene and younger basinal sedimentation. Streams, at least partially, kept pace with basin development, resulting in higher energy regime fluvial sedimentation in the younger deposits (Kuenzi 1966).

Pleistocene history of Montana is dominated by glacial and pluvial phenomena. Two periods of continental and contemporaneous mountain glaciation (Wisconsin and Illinoian) have been documented (Alden 1932 and 1953). On the northern Plains, continental glaciers flowed to approximately the vicinity of the present Missouri River, significantly influencing its present course. Several advances of glacial ice are recorded in fill that occupies the Flathead, Swan, and other valleys of the mountainous areas of the state.

A large lake formed in western Montana when the Clark Fork River was blocked by ice that advanced southward down the Purcell trench of northern Idaho. The resulting Glacial Lake Missoula occupied nearly all of the major valleys of Montana west of the continental divide. Thick accumulations of varved lake silts and clays in these valleys indicate that the lake existed during an extended interval. On the other hand, certain features, including giant ripple marks south of Hot Springs, and the Channeled Scablands of eastern Washington, indicate that the ice dam occasionally broke, resulting in catastrophic draining of the lake.

The most recent geologic activity evident in the study area has been dominated by erosional and fluvial processes. However, occasional earthquakes (see Section 6.2.1.3., Seismicity) provide reminders that some of the forces that have been responsible for Montana's overall geology are still active.

K2 Structure

The diversity of geologic structures in Montana is matched by few other areas of its size in the world.

Least deformed are the sedimentary strata of the eastern portion of the study area. Barely perceptible to the casual traveler, these nearly horizontal layers are warped into a number of domes, basins, synclines, and anticlines. Notable amongst them are the Bull Mountain Basin north of Billings, the Powder River Basin, mainly south of Forsyth, and the Porcupine Dome, northwest of Forsyth, all evident on the General Geology map.

Even in this area of little-deformed strata, there exist locally abundant normal faults. Those that occur in areas underlain by coal of the Fort Union Formation are small in size and displacement, and probably resulted from differential compaction of the coal (Pierce 1936). Other normal faults are arranged en echelon within the 110-mile-long Lake Basin-Huntley fault zone, which is considered to have resulted from transverse faulting within basement rock (Weidman 1965).

Central Montana contains both the plains-type structure of the east, and some structures characteristic of the western part of the state, as well as structures unique to central Montana. A major plains structure is the Crazy Mountain Basin which originated as a sedimentary basin in late Cretaceous time. Superimposed upon this basically simple structure, however, are large north-south folds, especially on the northwest side of the basin (Thom 1957), and intrusive masses which form the bulk of the Crazy Mountains.

Structures unique to the central area are isolated domal uplifts, of which the Little Belt, Snowy, and Big Horn Mountains are prominent examples. Smaller uplifts include the Highwood and Mocassin Mountains, and even smaller features such as Skull Butte, south of Stanford, and Gorden Butte, southeast of the Castle Mountains. These smaller domes were caused by upward intrusion of igneous rocks. The cause of the larger uplifts, as well as some smaller ones which have experienced repeated reversals of vertical movement (Norwood 1965) is related to differential vertical movement of crustal blocks.

The structure of western Montana is, by far, the most complex within the study area. Western Montana has endured major transverse faulting and repeated periods of compressional and extensional stresses.

The compressional stresses are evidenced in two forms. The first is folding, common in pre-middle Tertiary strata. Thrust faulting, the other manifestation, occurs mainly within a broad belt which extends from the Townsend-Three Forks area to northwest of Augusta. These thrust faults are most visible in the Sawtooth Range, west of Choteau, where numerous, separate thrusts cause Paleozoic and Mesozoic layers to be repeated again and again along an east-west traverse of the range.

The history and extent of transverse faulting in western Montana is difficult or impossible to determine. In some cases this type of faulting can only be inferred. Where best documented, just west of the northwest corner of the study area, displacement of three large transverse faults is on the order of 12 to 16 miles (Weidman 1965). One of these faults is in line with part of the Clark Fork Valley and other linear features, including the Lake Basin-Huntley fault zone. Together they form the somewhat vaguely defined Montana Lineament, which extends from the Hardin area to northern Idaho. Although it cannot be demonstrated on all of the best expressed portions of this apparent lineament that fault movement has been horizontal, other faults, some only inferred by their topographic expression, lie parallel to it, and imply that the Montana Lineament formed as part of a major crustal shear zone.

The structures responsible for most of the present large mountain ranges and valleys of western Montana are the result of extensional stresses. The normal faults which occurred have broken the earth's crust in here into large blocks. Crustal blocks which have sunk relative to others form the broad, intermontans valleys, and blocks which have risen create the mountain ranges.

In addition to the major structures, rocks of the study area have also been affected on localized scales. Faults, for example, frequently involve zones that are tens or hundreds of feet thick. The rock within these zones may be sheared, fractured, and pulverized by movement along the fault. All rocks, including even the barely deformed strata of eastern Montana, contain abundant fractures. These features have important engineering implications, because they frequently control the strength and other physical properties of rock.

K3 Stratigraphy and Igneous Rocks

The following discussion of the stratigraphic units and igneous rocks present in the study area is generalized. Subdivision of the units is based partly on natural stratigraphic groupings, and is partly arbitrary, for purposes of simplification. Most of the formations vary significantly in thickness and frequently, in character from one part of the study to another. Likewise, not all of the units are everywhere present, either originally, or at present, due to erosion. The rock units discussed are indicated on the General Geology map.

Precambrian Metamorphic Rocks (p €g)

The oldest rocks in the study area outcrop mainly in the Little Belt Mountains and south and west of Bozeman. They include gneiss, schist, quartzite, and marble, yielding metamorphic dates which range from 1.6 to 2.7 billion years (McMannis 1965). These rocks underly most or all of the younger rocks of Montana.

Precambrian Belt Group (p €b)

Rocks of the Belt Group, dating from around one billion years ago (McMannis 1965), form most of the non-igneous, non-metamorphic, mountains of western Montana. Belt strata primarily include argillites, silty carbonates, and quartzite. However, in the eastern portion of the Belt area, where strata were not so deeply buried, some of the fine-grained units have more the character of shale. These shale strata tend to weather rapidly, forming more topographically subdued areas than the other Belt lithologies.

Cambrian-Ordovician (€)

The oldest Cambrian sediments in Montana were deposited in Middle Cambrian, resting unconformably on Belt strata in the west, and on pre-Belt rocks in the south and east. Over most of the study area, Cambrian strata contain a basal sandstone (Flathead sandstone), an intermediate shale (Wolsey shale), and upper limestones (Meagher and others).

Ordovician strata outcrop only in a small part of the study area south of Livingston, as the Bighorn Dolomite. It is not differentiated from Cambrian on the Geologic Map of the Study Area.

Devonion-Permian (PD)

Where they occur in the study area, Middle Devonion strata lie unconformably upon Cambrian rocks. Devonion and Mississippian sedimentation was dominated by thick carbonate deposition (Jefferson, Madison, Amsden Formations), with minor amounts of anhydrite (Potlatch Formation), shale (Three Forks Formation), and sands (Big Snowy Group). The carbonates, resistant to weathering and erosion, form rugged, light gray or white mountains in much of their outcrop areas.

Pennsylvanian sediments contain widespread, clean white sands (Quadrant-Tensleep Formations). Permian deposition includes limestone, shales, and sands. A thin, but geologically unusual and economically significant deposit of phosphate (Phosphoria Formation) occurs in the southwestern study area.

Triassic and Jurassic (JT)

The Triassic period was mainly a time of widespread erosion in Montana. Minor areas of marine deposition (Woodside and Thanes Formations) outcrop in the corner of the study area southwest of Butte.

By Middle Jurassic time, marine seas again spread over most of Montana, depositing sand, shale, and limestone of the Ellis Group. Gypsum occurring in the lower part of the Ellis is mined near Lewistown. Near the end of the Jurassic, terrestrial muds and sands were deposited as the Morrison Formation, notable in that it contains many dinosaur remains, as well as the oldest coals in Montana.

Cretaceous Kootenai Formation and Colorado Group (Kkc)

The Kootenai Formation contains a basal sandstone (conglomerate in western Montana), several hundred feet of red shale and minor sands, and an upper limestone. The shale weathers into conspicuous red soil, especially in the north central portion of the study area.

In most of the study area, the Colorado Group consists of several thousand feet of gray and black soft shale, easily weathered to rounded, gently rolling areas of relatively low relief. Westward, near Garrison, Colorado Group strata is much thicker and contains much more coarse debus. Also, part of the dark shale that exists here is cemented to porcellainite, so that is overall character in the Garrison area is fundamentally different from elsewhere.

Montana Group, Livingston, Hell Creek, and Fort Union Formations (Km, Tkl, Khc, Tfu)

This is a complex group of sandstones, shales, siltstones, and mudstones that were deposited under alternating marine and nonmarine conditions. Several formations (Telegraph Creek Formation, a transitional sandy shale, Eagle Sandstone, and Bearpaw Shale) are relatively continuous from the eastern to the northwestern central part of the study area.

The Livingston Formation, lying immediately above the Eagle Sandstone, is a very thick sequence of andesitic sandstones, conglomerates, and shale, apparently derived from the nearby Elkhorn Mountains volcanic source (McMannis 1955). These sediments intertongue to the east with shales and sandstones of the Montana Group (Claggett Shale, Judith River Sandstone, Bearpaw Shale), Hell Creek Formation, and lower Fort Union Formation (McMannis 1955) (For a more detailed description of these eastern formation, see Section 11.1.4.4., Power Plant Volume). The only Montana Group equivalent in the Garrison area is a thick, locally exposed conglomerate (Golden Spike Formation).

In the Crazy Mountain basin, where the Livingston Formation is at its thickest (at least 14,000 feet, McMannis 1955), the shale is a significant valley-forming unit, underlying the valleys that extend northward and eastward from Bozeman Pass.

The Tongue River Member of the Fort Union Formation, overlying the Livingston Formation and its equivalents, contains Montana's economically strippable coal seams, interbedded with persistent, massive sandstones.

Tertiary and Cretaceous Volcanic Rocks (TKv)

The most extensive volcanism evident in the study area occured in the form of the Elk Mountain Volcanics, which mantled much of the same area southwest of Helena that was later intruded by the Boulder Batholith. As mentioned above, this thick, andesitic accumulation was also the source of much of the Livingston Formation, deposited in the Crazy Mountain Basin to the east. The Livingston Igneous Series (McMannis 1955), occurring extensively south of Big Timber, also provided a local source for these sediments.

Alkaline volcanic rocks are exposed in many locations in the north-central part of the study area. They include volcanics of the Adel or Birdtail Mountains southwest of Great Falls, and of the Highwood Mountains east of Great Falls.

Felsic lavas which originated in middle and late Tertiary time occur in some large areas in the southwest portion of the study area. These eruptions apparently provided the source of much of the volcanic ash and tuff that was deposited in the western fault-block basins during this period.

Tertiary and Cretaceous Intrusive Rocks (TKi)

Most granitic masses of Tertiary and Cretaceous age are scattered through the southwest portion of the study area. The largest, the Boulder Batholith, extends from the area of Helena to beyond Butte. Others, smaller and more widely scattered, occur from the southwest to the north-central portion. Most metallic ore deposits occur in veins that are associated with these rocks.

A number of alkaline rich-laccoliths are scattered throughout a large area in the central part of the state (Highwood Mountains, Moccasin Mountains, and others). Some of these contain exotic, layered mineral assemblages.

Tertiary Deposits (Ts)

Tertiary sedimentary strata younger than the Fort Union Formation occurs extensively within the basins of the western part of the study area. Much of this material is volcanic ash and tuff, possibly from nearby sources. The remainder, commonly coarsening toward the valley margins (Robinson 1963), is largely erosional debris from the upland areas. The ash weathers to bentonite, a clay that is particularly susceptible to landslide hazard when wet.

The younger Tertiary valley-fill sediments tend to be coarser-grained than the early deposits, reflecting a change to higher energy fluviatile environments (Kuenzi 1966).

Late Tertiary gravel deposits cover large areas in the north-central portion of the study area, near the Big Snowy Mountains, and are locally preserved elsewhere.

Quaternary (Qal, Qg)

The most widespread Quaternary deposits (Qg) are glacial in origin. They include three general kinds of materials: till, varved lake sediments, and outwash deposits.

The character of each of these deposits varies somewhat. The lake sediments, for example, contain variable proportions of silt and clay, dependent largely on distance from inlet streams or glaciers. The nature of till depends greatly on its source material---tills of the plains contain abundant expandable clay derived from erosion of Mesozoic shales, significantly affecting their physical properties. Likewise, glacial reworking of previously deposited glacial sediments has locally caused anomalous quantities of silt and clay, or gravel within the till.

Glacial deposits occur mainly in the northern and western portions of the study areas. Most of the lake sediments were deposited in Glacial Lake Missoula (see Appendix K1, Geologic History), and in Glacial Lake Great Falls, which covered the area around that city. The bulk of the remaining deposits is till. Most of these deposits occupy valley bottoms, although in some areas, as near the southern end of the Swan Valley, glacial till extensively mantles the low mountains and ridges.

Quaternary alluvial sediments (Qal) occur along most streams in the study area, in the form of terrace and floodplain deposits. Alluvial fans are other common alluvial deposits.

K4 Economic Geology

Geologic resources fall into three categories: metallic, non-metallic, and fuel.

Most of the metallic ore deposits occur within a large area encircling Helena, Philipsburg, and Butte. Local deposits are found throughout western Montana and in the isolated mountains of the central part of the state. Almost all of the metallic ores are vein deposits. At Butte, ore is also finely disseminated throughout its host rock. In the study area metalliferous deposits are almost invariably associated with Late Mesozoic or Tertiary age granitic intrusives, implying a genetic relationship.

Oil and gas are confined to sedimentary rocks of the eastern and central portions of the study area. They are found in localized structural and stratigraphic traps, at depths that generally exceed several thousand feet. Within the study area, production comes mainly from an area bounded by Lewistown on the west and Hardin on the east (after Perry 1962).

Coal occurs in the study area in sedimentary rocks of late Jurassic, middle Upper Cretaceous, latest Cretaceous, and early and middle Tertiary age. The oldest coal, in the Great Falls-Lewistown coal field, is bituminous. The youngest coal lies in the Tertiary basins of western Montana, and is localized in area, high in ash, and low-grade. Cretaceous coals are all uneconomically thin. By far the thickest and most extensive coals are contained in the early Tertiary Fort Union Formation, within this formation, the grade of the coal changes progressively from lignite in northeastern Montana, to subbituminous in the Powder River Basin south of Forsyth and to bituminous in the Red Lodge coal field southeast of Livingston (Perry 1962). The subbituminous coals of the Powder River Basin are of particular interest, because they would fuel the proposed Units 3 & 4 at Colstrip. (For a more detailed discussion of Fort Union coal, see Volume 2, Section 6.2.1.).

Almost all of the non-metalic geologic resources in the study area are sedimentary deposits: limestone, gypsum, clay, phosphate, silica, building stone, sand, and gravel. One non-sedimentary resource, no longer being actively mined, consists of saphires that occur on the northeast flank of the Little Belt Mountains, in upper Rock Creek west of Philipsburg, and along several creeks northwest of Butte.

APPENDIX L: Vegetation

APPENDIX L1

Vegetation Species List

* Noxious
** Poisonous

TREES

Cottonwood	*Populus trichocarpa*
Boxelder	*Acer negundo*
Common juniper	*Juniperus communis*
Douglas fir	*Pseudotsuga menziesii*
Engelmann spruce	*Picea engelmannii*
Grand fir	*Abies grandis*
Green ash	*Fraxinus pennsylvanica*
Horizontal juniper	*Juniperus horizontalis*
Limber pine	*Pinus flexilis*
Lodgepole pine	*Pinus contorta*
Mountain hemlock	*Tsuga mertensiana*
Mountain maple	*Acer glabrum*
Ponderosa pine	*Pinus ponderosa*
Quaking aspen	*Populus tremuloides*
Rocky Mountain juniper	*Juniperus scopulorum*
Subalpine fir	*Abies lasiocarpa*

TREES (Continued)

Western hemlock	*Tsuga heterophylla*
Western larch	*Larix occidentalis*
Western red cedar	*Thuja plicata*
Western white pine	*Pinus monticola*
Whitebark pine	*Pinus albicaulis*
Willow	*Salix* spp.

SHRUBS

Big sagebrush	*Artemisia tridentata*
Big whortleberry	*Vaccinium membranaceum*
Bitterbrush	*Purshia tridentata*
*Broom snakeweed	*Gutierrezia sarothrae*
Buffaloberry	*Shepherdia canadensis*
Chokecherry	*Prunus virginiana*
Curlleaf mountain mahogany	*Cercocarpus ledifolius*
Devil's club	*Oplopanax horridum*
Dogwood	*Cornus stolonifera*
Dwarf huckleberry	*Vaccinium caespitosum*

SHRUBS (continued)

Evergreen ceanothus	*Ceanothus velutinus*
Fringed sage	*Artemisia frigida*
**Greasewood	*Sarcobatus vermiculatus*
Grouse whortleberry	*Vaccinium scoparium*
**Horsebrush	*Tetradymia canescens*
Kinnikinnick	*Arctostaphylos uva-ursi*
Menziesia	*Menziesia ferruginea*
Ninebark	*Physocarpus malvaceus*
Nuttal saltbush	*Atriplex nuttallii*
Oregon grape	*Mahonia repens*
Pachistima	*Pachistima myrsinites*
*Pricklypear	*Opuntia polyacantha*
Red mountain heath	*Phyllodoce empetriformis*
Red stem ceanothus	*Ceanothus sanguineus*
Rose	*Rosa* spp.
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Serviceberry	*Amelanchier alnifolia*
Shadscale saltbush	*Atriplex confertifolia*
Shrubby cinquefoil	*Potentilla fruticosa*

SHRUBS (continued)

Silver sagebrush	*Artemisia cana*
Skunkbush sumac	*Rhus trilobata*
Snowberry	*Symphoricarpos albus*
Snow willow	*Salix nivalis*
Soapweed	*Yucca* spp.
Summit willow	*Salix saximontana*
Thimbleberry	*Rubus parviflorus*
Western ledum	*Ledum glandulosum*
Western snowberry	*Symphoricarpos occidentalis*
Winterfat	*Eurotia lanata*

GRASSES

Alkali bluegrass	*Poa juncifolia*
Alkali sacaton	*Sporobolus airoides*
Alpine bluegrass	*Poa alpina*
Alpine timothy	*Phleum alpinum*
**Arrowgrass	*Triglochin maritima*
Basin wildrye	*Elymus cinereus*
Bentgrass	*Agrostis* spp.

GRASSES (continued)

Bluegrass	Poa spp.
Bluebunch wheatgrass	Agropyron spicatum
Blue grama	Bouteloua gracilis
Buffalograss	Buchloe dactyloides
Canada bluegrass	Poa compressa
*Cheatgrass brome	Bromus tectorum
Elk sedge	Carex geyeri
Great basin wild-rye	Elymus cinereus
Green needlegrass	Stipa viridula
Idaho fescue	Festuca idahoensis
Indian ricegrass	Oryzopsis Hymenoides
Kentucky bluegrass	Poa pratensis
Little bluestem	Andropogon scoparius
Native bluegrass	Poa secunda
Needle-and-thread	Stipa comata
Needleleaf sedge	Carex stenophylla
Parry oatgrass	Danthonia parryi
Pine reedgrass	Calamagrostis rubescens
Plains muhly	Muhlenbergia cuspidata

GRASSES (continued)

Plains reedgrass	Calamagrostis montanensis
Prairie junegrass	Koeleria cristata
Prairie sandreed	Calamovilfa longifolia
Richardson's needlegrass	Stipa richardsonii
Rough fescue	Festuca scabrella
Saltgrass	Distichlis stricta
Sand dropseed	Sporobolus cryptandrus
Sedge	Carex spp.
Side-oats grama	Bouteloua curtipendula
*Sheep fescue	Festuca ovina
Squirreltail	Sitanion hystrix
Threadleaf sedge	Carex filifolia
Red three-awn	Aristida longiseta
Timber oatgrass	Danthonia intermedia
*Tumblegrass	Schedonnardus paniculatus
Western wheatgrass	Agropyron smithii
Wire rush	Juncus balticus

FORBS

Alpine forget-me-not	Eritrichium howardii
Arnica	Arnica cordifolia
Arrowleaf balsamroot	Balsamorhiza sagittata
Aster	Aster conspicuus
Ballhead sandwort	Arenaria congesta
Beargrass	Xerophyllum tenax
Bluebell	Mertensia spp.
*Burdock	Arctium lappa
*Canada thistle	Cirsium arvense
*Clubmoss	Selaginella spp.
**Cocklebur	Xanthium strumarium
Common salsify	Tragopogon dubius
Cudweed sagewort	Artemisia ludoviciana
*Dalmation toadflax	Lineria dalmatica
**Death camas	Zigadenus venenosus
False Solomon's seal	Smilacina racemosa
*Field bindweed	Convolvulus arvensis
Glacier lily	Erythronium grandiflorum
Groundsel	Senecio spp.

FORBS (continued)

Hoods phlox	Phlox hoodii
Lady fern	Athyrium filix-femina
*Lambsquarter goosefoot	Chenopodium album
**Leafy spurge	Euphorbia esula
**Locoweed	Oxythropis spp.
**Low larkspur	Delphinium bicolor
**Lupine	Lupinus spp.
**Milkvetch	Astragalus spp.
*Phlox	Phlox spp.
Prairie groundsel	Senecio plattensis
Pussytoes	Antennaria spp.
Queencup beadlily	Clintonia uniflora
Russian thistle	Salsola kali
Scarlet globemallow	Sphaeralcea coccinea
Silverleaf scurfpea	Psoralea argophylla
*Spotted knapweed	Centaurea maculosa
Spreading fleabone	Erigeron pumilus
**St. John's-wort	Hypericum perforatum
*Stickweed	Hackelia deflexa

FORBS (continued)

Sweetscented bedstraw	Galium triflorum
Tansy	Tanacetum vulgare
Vetch	Vicia sativa
**Water hemlock	Cicuta douglasii
*Whitetop	Cardaria draba
Wild buckwheat	Eriogonum annuum
Wild licorice	Glycyrrhiza lepidota
Wild onion	Allium cernuum
Yarrow	Achillea millefolium
Yellow sweetclover	Melilotus officinalis

APPENDIX L2 (CONT.)

VEGETATION TYPE	No. 16 Big Sagebrush-Western Wheatgrass-Grama	No. 17 Big Sagebrush-Western Wheatgrass-Needle & Thread-Grama	No. 18 Big Sagebrush-Grass	No. 19 Silver Sagebrush-Grass	No. 20 Silver Sagebrush-Greasewood	No. 21 Alpine	No. 22 Bluebunch Wheatgrass-Fescue	No. 23 Bluebunch Wheatgrass-Needle & Thread	No. 24 Western Wheatgrass-Needle & Thread-Green Needlegrass	No. 25 Western Wheatgrass-Needle & Thread-Grama	No. 26 Needle & Thread-Western Wheatgrass-Grama	No. 27 Needle & Thread-Sand Dropseed	No. 28 Grama-Needle & Thread	No. 29 Badlands
Principal Associated Species Trees							Limber pine Horizontal juniper							Rocky Mountain juniper Ponderosa pine
Shrubs	Pricklypear Fringed sage	Fringed sage Pricklypear	Rubber rabbitbrush Fringed sage Pricklypear Broom snakeweed	Broom snakeweed Pricklypear	Nuttall saltbush Rose Cudweed sagewort	Snow willow Summill willow Western ledum Red mountain heath	Shrubby cinquefoil Big sagebrush Fringed sage Skunkbush sumac	Fringed sage Broom snakeweed Rubber rabbitbrush Big sagebrush	Fringed sage Big sagebrush	Big sagebrush Pricklypear Silver sagebrush Fringed sage	Broom snakeweed Pricklypear		Fringed sage	Greasewood Nuttall saltbush Shadscale saltbush Fringed sage Winterfat Big sagebrush
Grasses & grasslike	Prairie sandreed Prairie junegrass Threadleaf sedge Plains muhly	Prairie junegrass Native bluegrass Plains reedgrass Threadleaf sedge Plains muhly	Native bluegrass Prairie junegrass Blue grama Bluebunch wheatgrass Idaho fescue Plains muhly Needle and thread	Blue grama Needle and thread Buffalograss Tumblegrass Threadleaf sedge Bluebunch wheatgrass	Green needlegrass Saltgrass Wirerush Alkali bluegrass Basin wildrye Buffalograss	Sheep fescue Timber oatgrass Bentgrass Alpine bluegrass Alpine timothy Sedge	Western wheatgrass Prairie junegrass Threadleaf sedge Needle and thread Kentucky bluegrass Side-oats grama	Prairie junegrass Threadleaf sedge Indian ricegrass Blue grama	Prairie junegrass Threadleaf sedge Canada bluegrass Blue grama Native bluegrass	Native bluegrass Green needlegrass Prairie junegrass Plains reedgrass Plains muhly Threadleaf sedge	Threadleaf sedge Native bluegrass Prairie junegrass Plains reedgrass Bluebunch wheatgrass Needleleaf sedge	Bluebunch wheatgrass Indian ricegrass Prairie junegrass Threadleaf sedge Green needlegrass	Native bluegrass Prairie junegrass Bluebunch wheatgrass Needleleaf sedge Threadleaf sedge	Alkali sacaton Squirreltail Bluebunch wheatgrass Indian ricegrass Little bluestem Blue grama Buffalograss Tumblegrass Prairie sandreed Western wheatgrass Red three awn
Forbs	Scurfpea Clubmoss Wild buckwheat	Wild buckwheat Phlox Scarlet globemallow	Pussytoes Phlox Locoweed Lupine	Scarlet globemallow Lambsquarter goosefoot Clubmoss Silverleaf scurfpea	Wild licorice	Lupine Bluebell Alpine forget-me-not	Lupine Yarrow Wild onions Arrowleaf balsamroot	Locoweed Lupine Clubmoss Yarrow	Yarrow Lupine Phlox Clubmoss	Phlox Wild buckwheat Scarlet globemallow	Scarlet globemallow Lambsquarter goosefoot Stickweed	Yarrow Clubmoss Phlox	Phlox Lupine Clubmoss	Silverleaf scurfpea Russian thistle Hoods phlox
Geographical Area(s)	eastern Montana	eastern Montana	eastern Montana central Montana & western Montana	eastern Montana	eastern Montana	south central Montana	western Montana & central Montana	west central montana	central Montana & eastern Montana	central & eastern Montana	eastern Montana & central Montana	south central Montana	eastern Montana	eastern Montana
Topography	foothills plains	foothills plains	foothills	draw bottoms and rolling hills	creek bottoms and rolling hills	rolling to very steep, above timberline	rolling hills-steep, from edge of timber in mountains to plains	rolling hills	gently sloping to rolling	plains to rolling and rough	rolling	gently sloping	gently sloping to rolling	rough breaks
Elevation (ft) (MSL)	3,100 - 4,200	3,100 - 4,200	3,100 - 4,400	3,100 - 4,200'	3,100 - 4,000'	above 9,500	3,000 - 6,000'	3,000 - 3,800	3,000 - 4,800'	3,000 - 4,800'	3,000 - 5,000	3,500 - 4,200	3,000 - 4,200	3,000 - 4,000'
Exposure	flat to southerly	west & south	south	variable	variable	variable	bluebunch—south & southwest slopes, fescues—north & west slopes	variable mostly southwest	variable	variable	variable	west & south	variable	variable
Precipitation Zone (ann.)	12-16	12-16	10-14	10-14"	10-14"	above 30"	10-20"	14-20'	10-20"	10-14"	10-14	14-20"	10-14	10-14
Soils	loams	silty to sandy loams	shaley soils, clay loam	clay loam silty loam	clay loam, silt loam and sometimes sandy loam alkaline	shallow, course sandy to rocky loam	shallow, sandy to gravelly loams; rocky	sandy to gravelly	shales and where clay or clay loam in B horizon	shales and where there is clay or clay loam in B horizon; heavy soils, sandy to gravelly	"A" & "B" horizons silty to sandy loams	alluvial material	variable, grama more prevalent on dryer sites	shaly clay
Major Resource Uses	watershed range wildlife	watershed range wildlife	watershed wildlife range	watershed range wildlife	watershed wildlife range	recreation summer sheep range	range wildlife recreation	range wildlife	range cultivation (Cascade county)	range wildlife	range wildlife	range watershed wildlife cultivation	range wildlife	wildlife limited range recreation
Remarks	Blue grama increases with heavy grazing	Blue grama increases with heavy grazing			dominance depends on salinity and depth of moisture	very sensitive	With increased elevation the Fescues assume dominance and bluebunch is uncommon			big sagebrush throughout in minor quantities. blue grama increases with heavy grazing	blue grama increases with heavy grazing	on alluvial fans at base of glaciated mountains	blue grama increases with heavy grazing	very sensitive to disturbance very sparse vegetation

APPENDIX L2

VEGETATION TYPE	No. 1 Subalpine	No. 2 Lodgepole Pine	No. 3 Spruce-Fir	No. 4 Western Larch	No. 5 Douglas Fir	No. 6 Western Ponderosa Pine	No. 7 Eastern Ponderosa Pine	No. 8 Ponderosa Pine Savanna	No. 9 Limber Pine-Juniper	No. 10 Juniper-Complex	No. 11 Cottonwood-Willow-Dogwood	No. 12 Cottonwood-Willow	No. 13 Boxelder-Green Ash-Rose-Chokecherry	No. 14 Big Sagebrush-Bluebunch Wheatgrass	No. 15 Big Sagebrush-Western Wheatgrass
Principal Associated Species Trees	Subalpine fir Engelmann spruce Lodgepole pine Douglas fir Mountain hemlock Whitebark pine	Subalpine fir Engelmann spruce Douglas fir Ponderosa pine Quaking aspen Whitebark pine	Englemann spruce Subalpine fir Douglas fir Western larch Grand fir Western red cedar Lodgepole pine	Lodgepole pine Grand fir Douglas fir Ponderosa pine Western white pine Western redcedar	Ponderosa pine Lodgepole pine Western larch Limber pine Engelmann spruce Subalpine fir	Western larch Douglas fir Lodgepole pine Limber pine	Rocky Mountain juniper Horizontal juniper	Rocky Mountain Juniper	Lodgepole pine Douglas fir	Ponderosa pine Cottonwood	Douglas fir Subalpine fir				
Shrubs	Grouse whortleberry [illegible] Devil's club [illegible] Menziesia	Bitterbrush Dwarf huckleberry Big whortleberry	Grouse whortleberry Big whortleberry Menziesia Devil's club Ninebark Snowberry	Ninebark Pachistima Serviceberry Kinnikinnick Snowberry	Ninebark Oregon grape Fringed sage Snowberry Big sagebrush Dwarf huckleberry	Snowberry Ninebark Oregon grape Chokecherry Bitterbrush	Skunkbush sumac Western snowberry	Western snowberry Skunkbush sumac	Big sagebrush Silver sagebrush Soapweed Skunkbush sumac	Big sagebrush Rubber rabbitbrush Broom snakeweed Skunkbush sumac Pricklypear Fringed sage Silver sagebrush Soapweed	Rose Thimbleberry Snowberry Serviceberry Chokecherry	Rose Buffaloberry Snowberry Chokecherry Serviceberry	Buffaloberry Silver sagebrush Snowberry Serviceberry	Rubber rabbitbrush Broom snakeweed Fringed sage	Broom snakeweed Pricklypear
Grasses & grasslike	[illegible] [illegible] [illegible] Elk sedge	Idaho fescue Pine reedgrass	Pine reedgrass Elk sedge	Pine reedgrass Elk sedge Idaho fescue	Rough fescue Pine Reedgrass Bluebunch wheatgrass Idaho fescue Elk Sedge	Bluebunch wheatgrass Pine reedgrass Idaho fescue Elk sedge	Bluebunch wheatgrass Needle and thread Blue grama Western wheatgrass	Bluebunch wheatgrass Western wheatgrass Blue grama Native bluegrass	Bluebunch wheatgrass Idaho fescue Rough fescue	Bluebunch wheatgrass Native bluegrass Threadleaf sedge Rough fescue	Sedges	Sedges Wirerush	Sedges Bluegrass	Idaho fescue Prairie junegrass Threadleaf Sedge	Prairie junegrass Prairie sandreed Green needlegrass
Forbs	Aster [illegible] Lupine Beargrass	Lupine	Beargrass Lady fern False Solomon's seal Groundsel Queencup beadlily	Beargrass Arnica Arrowleaf balsamroot Glacier lily	Beargrass Arrowleaf balsamroot Arnica False Solomon's seal	Arrowleaf balsamroot Lupine	Phlox Arrowleaf balsamroot	Phlox Lupine	Lupine	Clubmoss Pussytoes	False Solomon's seal Spotted knapweed	Lambsquarter goosefoot Stickweed	Burdock Lambsquarter goosefoot Sweetscented bedstraw	[illegible] Pussytoes Spreading fleabane Locoweed	Vetch Wild onion
Geographical Area(s)	western & central Montana	western & central Montana	western & central Montana	western Montana	central & western Montana	central and western Montana	eastern Montana	eastern Montana	central and eastern Montana	central and eastern Montana	western Montana	central Montana	eastern Montana	central Montana	central and eastern Montana
Topography	rough mountains	mountains rough & rocky to gentle slopes & basins	mountainous along streams, valley bottoms	mountainous to valleys bottoms benches & rolling tops	mountainous	mountainous foothills benches to plateaus	rough broken land along the Missouri and Yellowstone rivers and rocky hills rising from plains	rolling to hilly on breaks to terraces	mountainous ridge tops	rolling hills, breaks—drier slopes	bottomland, generally flat; river and creek bottoms	bottomland river and creek bottoms	bottomland river & creek bottoms	foothills	swales
Elevation (ft) (Mean Sea Level)	3,500 - 9,500	3,000 - 9,500	3,000 - 9,000'	3,000 - 7,000'	3,000 - 7,900'	3,300 - 6,000	3,000 - 4,500'	3,300 - 4,000	4,000 - 6,300'	3,000 - 5,000'	3,000 - 6,000'	3,100 - 6,000	3,100 - 4,500	3,100 - 4,500	3,100 - 4,500
Exposure	northerly but variable	variable best on northern and eastern	northerly	northerly	northerly to southerly	south and west	variable, denser stands on north and easterly	southerly ridgetops and swales	steep to rolling slopes and ridgetops	southerly & western	variable	variable	variable	south & west	flat to southerly
Precipitation Zone (annual)	20-30	18	45+	ave. 28	20 - 30'	10-21"	10-18	12 - 14	12-18	10-14"	10-20" +	14-20"	10-14"	14-20	12-16
Soils	sandy loams to rocky	silty loam to clay loam to bare gravel	young immature, silt and clay loam alluvial soils to coarse texture sands gravels	deep, porous soils, gravelly, sandy or loamy	sandy loams to clays best on porous loams, deep rich well drained	sandy loam, gravelly loam; silt loam, clay loam, loamy sand and gravel	rocky and gravelly, and poorly developed	stony, or gravelly to loams and alluvium	dry, shallow, rocky or gravelly; usually calcareous	moist gravelly or sandy soils	sandy, gravelly; or deep alluvial	gravelly, sandy, rich humus, some clay soils	gravelly sandy rich humus	rocky to gravelly loams	clay or clay loam in B horizon
Major Resource Uses	East of Divide: watershed, timber, wildlife, recreation, range West of Divide: watershed, wildlife, recreation, timber	East of Divide: timber, wildlife, watershed, recreation West of Divide: watershed, wildlife, recreation, timber	East of Divide: timber, wildlife, watershed, recreation West of Divide: watershed, wildlife, timber	timber watershed recreation wildlife	East of Divide: timber, recreation, wildlife, watershed, range West of Divide: timber, watershed, wildlife, recreation, range	wildlife timber recreation range watershed	range watershed wildlife recreation	watershed range wildlife	watershed wildlife range	watershed wildlife range	streambank stabilization, wildlife	streambank stabilization wildlife	streambank stabilization wildlife	watershed wildlife range	watershed range wildlife
Remarks	revegetation problems occur in the portion having a whitebark pine subtype which is from above 7,000 ft west of the divide and usually above 7,800 ft east of the divide but maybe below 6,000 ft										severe impact	severe	severe		

Environmental Relationships of Vegetation Types Within the Study Area

APPENDIX M: LAND USE

TABLE 1

LAND USE - 1958 AND 1967

County	Total Land Area	Federal Non Cropland 1958	Federal Non Cropland 1967	Urban and Built-up 1958	Urban and Built-up 1967	Small Water Areas 1958	Small Water Areas 1967	Cropland 1958	Cropland 1967
Beaverhead	3,549,870	2,108,346	2,026,539	16,505	18,505	3,306	3,260	98,000	240,000
Big Horn	3,217,626	33,662	32,062	10,827	11,979	676	700	298,021	286,480
Broadwater	766,720	244,320	245,039	8,640	8,840	30	881	95,000	106,345
Carbon	1,324,800	565,021	519,872	7,952	8,979	5,000	5,000	176,800	179,274
Cascade	1,701,760	219,460	221,915	35,000	40,046	4,089	4,089	495,607	489,919
Chouteau	2,508,800	160,682	145,919	26,839	27,839	7,500	7,500	1,100,000	1,102,263
Deer Lodge	472,320	153,068	158,352	14,254	19,951	500	500	14,992	16,892
Fergus	2,716,160	506,546	467,262	18,802	25,000	9,586	10,104	535,000	556,637
Flathead	3,289,600	2,354,707	2,411,649	17,049	17,347	6,524	6,524	131,500	115,679
Gallatin	1,610,880	657,988	647,600	18,100	20,080	3,500	3,500	296,000	266,288
Golden Valley	753,920	35,021	31,919	6,973	7,053	701	701	73,381	73,444
Granite	1,109,120	702,425	708,452	5,400	6,203	780	780	28,340	27,092
Jefferson	1,056,640	570,760	560,319	10,604	11,285	425	1,100	48,038	45,131

TABLE 1
(continued)

County	Pasture		Range		Forest		Other	
	1958	1967	1958	1967	1958	1967	1958	1967
Beaverhead	10,000	60,000	1,284,054	1,121,187	24,000	66,350	11,629	14,029
Big Horn	4,545	42,430	2,663,389	2,501,257	200,000	331,721	10,000	10,997
Broadwater	10,859	25,307	350,826	330,881	50,000	42,369	7,000	7,058
Carbon	4,200	19,704	539,074	539,074	14,000	42,594	12,753	10,303
Cascade	8,000	10,329	804,206	828,154	128,000	99,610	7,398	7,698
Chouteau	56,154	31,529	1,106,885	1,154,266	39,000	24,359	11,740	15,125
Deer Lodge	800	8,293	143,321	146,860	126,000	119,567	19,385	1,905
Fergus	41,968	58,000	1,381,068	1,384,969	219,000	199,772	4,190	14,416
Flathead	21,000	22,354	61,500	49,820	681,000	657,119	40,000	9,106
Gallatin	48,000	94,268	345,570	342,521	229,000	223,063	12,500	13,560
Golden Valley	24,500	21,000	595,344	595,880	13,000	21,908	5,000	2,015
Granite	7,353	11,645	206,440	182,634	151,000	159,411	7,382	2,903
Jefferson	6,080	21,870	353,563	317,223	61,000	92,812	6,125	6,900

TABLE 1
(continued)

County	Total Land Area	Federal Non Cropland		Urban and Built-up		Small Water Areas		Cropland	
		1958	1967	1958	1967	1958	1967	1958	1967
Judith Basin	1,203,200	309,318	310,233	9,690	9,777	-0-	372	285,000	286,855
Lake	960,000	162,397	171,123	13,503	19,155	5,000	5,000	128,500	115,471
Lewis & Clark	2,218,240	1,087,514	1,062,848	17,337	20,730	1,361	1,361	91,600	88,100
Madison	2,259,200	1,035,612	1,100,779	10,963	11,123	2,902	2,902	103,500	91,240
Meagher	1,506,560	457,736	452,169	6,770	7,024	3,000	3,000	57,235	79,165
Mineral	782,720	647,302	648,266	8,040	9,240	548	2,321	5,520	4,355
Missoula	1,672,320	717,019	714,713	13,500	18,000	861	4,989	61,000	43,646
Musselshell	1,207,040	123,410	117,930	13,822	14,100	1,485	1,485	71,460	62,905
Park	1,681,280	893,772	887,969	18,664	18,856	3,652	3,652	122,147	125,000
Powell	1,495,680	711,388	713,913	10,500	14,114	8,000	8,000	45,000	71,612
Ravalli	1,525,760	1,102,980	1,111,521	7,744	7,785	5,600	5,600	103,500	67,488
Rosebud	3,220,480	337,773	337,995	4,608	5,208	3,104	3,104	128,496	128,303
Sanders	1,791,360	923,961	922,688	14,232	14,232	1,547	6,541	54,265	46,487

TABLE 1
(continued)

County	Pasture		Range		Forest		Other	
	1958	1967	1958	1967	1958	1967	1958	1967
Judith Basin	20,000	22,250	548,586	551,084	29,000	18,139	1,606	4,490
Lake	28,500	80,891	196,600	180,472	402,000	375,863	23,500	12,065
Lewis & Clark	5,000	12,500	703,356	739,290	301,000	280,074	11,237	13,337
Madison	13,000	90,000	936,826	825,875	142,000	121,281	14,397	16,000
Meagher	2,000	10,000	815,931	783,619	159,000	165,195	4,888	6,388
Mineral	90	1,073	4,710	688	115,625	115,445	885	1,332
Missoula	2,500	14,000	97,500	74,079	772,440	790,303	8,500	12,590
Musselshell	17,828	24,505	732,168	733,882	241,000	242,405	5,867	9,828
Park	30,000	35,000	482,015	457,329	125,000	147,274	6,030	6,200
Powell	5,000	26,012	318,642	361,697	393,000	293,886	7,150	6,446
Ravalli	10,000	64,500	101,236	95,333	177,000	162,649	17,700	10,884
Rosebud	17,388	27,388	2,612,225	2,483,906	103,000	220,690	13,886	13,886
Sanders	13,105	30,516	154,080	250,948	624,000	510,255	6,000	9,693

TABLE 1
(continued)

County	Total Land Area	Federal Non Cropland 1958	Federal Non Cropland 1967	Urban and Built-up 1958	Urban and Built-up 1967	Small Water Areas 1958	Small Water Areas 1967	Cropland 1958	Cropland 1967
Silver Bow	458,240	245,215	238,204	11,516	13,316	70	411	3,653	5,980
Stillwater	1,150,080	197,261	192,870	9,853	10,456	863	863	227,659	247,078
Sweet Grass	1,181,440	287,916	299,040	7,040	7,630	540	540	83,441	84,507
Teton	1,468,160	312,535	281,774	17,286	17,401	4,000	4,000	523,000	551,514
Treasure	629,760	11,378	11,694	3,118	4,115	1,185	1,185	59,428	37,768
Wheatland	910,080	69,322	70,282	5,437	5,837	1,460	1,460	51,795	73,846
Yellowstone	1,686,400	93,835	85,230	41,033	44,333	470	500	307,806	284,816

Source: U.S.D.A. 1970

TABLE 1
(continued)

County	Pasture		Range		Forest		Other	
	1958	1967	1958	1967	1958	1967	1958	1967
Silver Bow	1,057	2,000	150,438	147,371	45,000	49,490	1,291	1,468
Stillwater	27,472	14,681	519,158	610,785	92,000	68,472	12,286	4,875
Sweet Grass	45,681	41,899	674,012	640,970	57,000	103,944	25,810	2,860
Teton	20,000	44,135	540,000	523,789	27,000	26,648	24,339	18,899
Treasure	40,783	8,127	487,813	523,289	24,000	38,603	2,055	4,979
Wheatland	28,000	29,873	745,066	716,586	6,000	9,607	3,000	2,589
Yellowstone	4,333	71,000	1,162,863	1,101,889	56,000	78,501	20,000	20,131

Source: U.S.D.A. 1970

TABLE 2

ACREAGES AND PRODUCTION OF ALL CROPS, IRRIGATED AND NOT IRRIGATED - 1971

Acres Harvested and Value of Crop Production

County	IRRIGATED Acres Harvested	IRRIGATED Value of Crop Production	NOT IRRIGATED Acres Harvested	NOT IRRIGATED Value of Crop Production
Beaverhead	142,650	$ 5,844,800	14,000	$ 381,400
Big Horn	34,910	2,317,300	122,400	4,404,300
Broadwater	29,210	2,651,500	41,100	1,060,500
Carbon	61,640	5,960,200	50,300	1,602,800
Cascade	21,650	1,642,200	275,300	8,649,700
Chouteau	11,440	654,300	726,700	23,624,900
Deer Lodge	13,760	1,073,200	800	29,200
Fergus	19,420	778,700	357,300	11,545,500
Flathead	19,913	2,031,600	70,800	3,798,200
Gallatin	79,030	5,379,500	113,600	4,244,400
Golden Valley	8,300	518,500	36,800	1,034,300
Granite	34,300	1,871,300	3,300	127,000
Jefferson	17,770	923,500	27,200	691,200
Judith Basin	9,200	378,300	166,000	5,214,400

TABLE 2
(continued)

County	IRRIGATED		NOT IRRIGATED	
	Acres Harvested	Value of Crop Production	Acres Harvested	Value of Crop Production
Lake	53,966	$ 6,004,400	40,000	$ 1,693,000
Lewis & Clark	28,250	1,568,600	33,800	989,600
Madison	90,250	5,222,600	16,900	592,800
Meagher	42,800	1,868,800	17,000	473,400
Mineral	800	61,500	2,400	139,300
Missoula	21,350	1,469,800	14,500	599,300
Musselshell	8,030	475,400	30,100	763,000
Park	52,505	3,021,300	36,600	1,270,900
Powell	49,390	2,885,500	13,400	423,700
Ravalli	43,640	4,109,600	8,500	300,700
Rosebud	26,860	2,009,700	52,600	1,566,400
Sanders	14,700	991,100	23,400	913,500

TABLE 2
(continued)

County	IRRIGATED Acres Harvested	IRRIGATED Value of Crop Production	NOT IRRIGATED Acres Harvested	NOT IRRIGATED Value of Crop Production
Silver Bow	5,740	$ 321,600	1,700	$ 44,900
Stillwater	19,510	1,367,500	117,600	3,451,000
Sweet Grass	35,705	1,942,900	35,100	1,051,400
Teton	78,350	5,146,200	246,500	7,926,000
Treasure	11,370	1,929,500	12,600	399,900
Wheatland	29,800	1,129,900	29,100	814,400
Yellowstone	38,590	6,182,500	121,500	4,175,800

Source: Montana Crop and Livestock Reporting Service 1972

TABLE 3

AVERAGE YIELDS OF CULTIVATED CROPS, 1971

	WHEAT		BARLEY		OATS		CORN[3]		RYE	
COUNTY	Acres[1]	Y/A[2]	Acres[1]	Y/A[2]	Acres[1]	Y/A[4]	Acres[1]	Y/A[4]	Acres[1]	Y/A[2]
Beaverhead	8,000	31.6	3,900	43.0	400	62.0	-0-	-0-	-0-	-0-
Big Horn	56,800	30.2	25,500	41.0	4,400	37.7	3,000	16.0	100	19.0
Broadwater	28,100	24.4	13,500	35.2	2,000	29.9	200	15.0	-0-	-0-
Carbon	19,200	29.2	17,200	41.4	5,200	48.7	2,300	19.5	-0-	-0-
Cascade	150,400	26.5	64,000	33.1	3,400	24.5	1,600	18.0	-0-	-0-
Chouteau	431,700	30.4	242,500	31.0	8,500	41.2	200	14.0	-0-	-0-
Deer Lodge	700	45.0	400	40.8	-0-	-0-	-0-	-0-	-0-	-0-
Fergus	140,300	30.7	99,500	36.0	7,500	39.7	200	15.0	-0-	-0-
Flathead	16,400	49.1	24,800	63.1	1,500	51.2	300	18.0	-0-	-0-
Gallatin	59,600	34.7	41,600	48.0	4,100	53.3	300	16.0	-0-	-0-
Golden Valley	15,100	26.9	8,000	33.0	4,500	27.4	-0-	-0-	-0-	-0-
Granite	700	31.1	1,000	54.5	300	46.0	-0-	-0-	-0-	-0-
Jefferson	8,300	21.3	3,300	34.8	3,500	30.0	-0-	-0-	-0-	-0-
Judith Basin	73,100	26.1	41,000	35.1	6,000	37.5	-0-	-0-	-0-	-0-

TABLE 3
(continued)

COUNTY	BEANS		POTATOES		SUGARBEETS		ALL HAY	
	Acres[1]	Y/A[5]	Acres[1]	Y/A[6]	Acres[1]	Y/A[4]	Acres[1]	Y/A[4]
Beaverhead	-0-	-0-	450	160	-0-	-0-	143,900	1.54
Big Horn	1,200	12.8	-0-	-0-	-0-	-0-	63,300	1.89
Broadwater	-0-	-0-	490	130	2,020	12.7	24,200	2.59
Carbon	2,600	20.2	-0-	-0-	7,480	17.9	60,100	2.18
Cascade	-0-	-0-	150	125	-0-	-0-	79,000	1.58
Chouteau	-0-	-0-	-0-	-0-	-0-	-0-	53,500	1.17
Deer Lodge	-0-	-0-	460	190	-0-	-0-	13,000	2.12
Fergus	-0-	-0-	-0-	-0-	-0-	-0-	128,700	1.07
Flathead	-0-	-0-	670	210	-0-	-0-	47,300	2.16
Gallatin	-0-	-0-	830	175	-0-	-0-	86,500	2.22
Golden Valley	-0-	-0-	-0-	-0-	-0-	-0-	17,200	1.56
Granite	-0-	-0-	-0-	-0-	-0-	-0-	35,600	1.92
Jefferson	-0-	-0-	170	115	-0-	-0-	29,700	1.59
Judith Basin	-0-	-0-	-0-	-0-	-0-	-0-	55,100	1.23

TABLE 3
(continued)

County	WHEAT		BARLEY		OATS		CORN[3]		RYE	
	Acres[1]	Y/A[2]	Acres[1]	Y/A[2]	Acres[1]	Y/A[4]	Acres[1]	Y/A[4]	Acres[1]	Y/A[2]
Lake	11,300	42.6	8,900	48.9	1,700	63.2	600	16.0	100	12.0
Lewis & Clark	13,300	26.2	5,600	31.3	2,600	33.6	200	14.0	-0-	-0-
Madison	10,100	30.5	4,100	48.1	900	49.8	-0-	-0-	-0-	-0-
Meagher	4,600	27.8	3,900	27.2	600	37.5	-0-	-0-	-0-	-0-
Mineral	500	35.6	200	45.0	200	54.0	-0-	-0-	-0-	-0-
Missoula	4,900	32.9	2,800	47.5	1,400	50.7	300	18.0	-0-	-0-
Musselshell	11,500	24.8	7,200	27.4	600	36.5	400	16.0	100	25.0
Park	17,300	29.7	8,500	33.1	2,300	50.8	100	18.0	-0-	-0-
Powell	1,900	40.4	4,800	43.9	1,400	28.3	-0-	-0-	-0-	-0-
Ravalli	3,700	37.5	6,100	56.4	700	43.1	500	17.0	-0-	-0-
Rosebud	17,300	28.2	14,600	42.1	4,100	46.9	1,300	15.0	-0-	-0-
Sanders	4,500	30.2	2,900	45.6	500	41.2	-0-	-0-	-0-	-0-

TABLE 3
(continued)

COUNTY	BEANS		POTATOES		SUGARBEETS		ALL HAY	
	Acres[1]	Y/A[5]	Acres[1]	Y/A[6]	Acres[1]	Y/A[4]	Acres[1]	Y/A[4]
Lake	-0-	-0-	2,370	210	-0-	-0-	68,700	2.05
Lewis & Clark	-0-	-0-	-0-	-0-	-0-	-0-	40,500	1.62
Madison	-0-	-0-	250	215	-0-	-0-	91,800	2.21
Meagher	-0-	-0-	-0-	-0-	-0-	-0-	50,700	1.42
Mineral	-0-	-0-	-0-	-0-	-0-	-0-	2,300	2.52
Missoula	-0-	-0-	-0-	-0-	-0-	-0-	26,600	2.26
Musselshell	-0-	-0-	-0-	-0-	-0-	-0-	18,200	1.34
Park	-0-	-0-	-0-	-0-	-0-	-0-	60,800	2.08
Powell	-0-	-0-	390	180	-0-	-0-	54,300	1.82
Ravalli	-0-	-0-	800	195	740	18.2	40,100	2.85
Rosebud	-0-	-0-	-0-	-0-	1,560	18.1	38,800	1.82
Sanders	-0-	-0-	-0-	-0-	-0-	-0-	30,100	1.90

TABLE 3
(continued)

COUNTY	WHEAT		BARLEY		OATS		CORN[3]		RYE	
	Acres[1]	Y/A[2]	Acres[1]	Y/A[2]	Acres[1]	Y/A[4]	Acres[1]	Y/A[4]	Acres[1]	Y/A[2]
Silver Bow	-0-	-0-	100	40.0	100	50.0	-0-	-0-	-0-	-0-
Stillwater	52,000	26.9	36,000	33.3	8,800	35.2	1,700	18.5	-0-	-0-
Sweet Grass	8,500	24.4	11,000	33.5	1,500	49.1	-0-	-0-	-0-	-0-
Teton	160,200	30.9	100,000	38.6	3,000	44.0	-0-	-0-	-0-	-0-
Treasure	4,100	30.6	2,300	57.7	400	75.0	1,600	18.0	-0-	-0-
Wheatland	9,400	25.2	8,800	33.2	1,200	36.7	-0-	-0-	-0-	-0-
Yellowstone	77,100	30.4	39,500	40.0	2,400	53.0	10,600	18.0	-0-	-0-

1 - Acres harvested
2 - Yield per acre--bushels
3 - Irrigated silage only
4 - Yield per acre--tons
5 - Yield per acre--100 pound bags (cleaned)
6 - Yield per acre--Cwt (hundred weight)

SOURCE: Montana Crop and Livestock Reporting Service 1972

TABLE 3
(continued)

COUNTY	BEANS		POTATOES		SUGARBEETS		ALL HAY	
	Acres[1]	Y/A[5]	Acres[1]	Y/A[6]	Acres[1]	Y/A[4]	Acres[1]	Y/A[4]
Silver Bow	-0-	-0-	-0-	-0-	-0-	-0-	7,200	1.90
Stillwater	300	19.3	-0-	-0-	1,160	20.9	38,800	1.42
Sweet Grass	-0-	-0-	-0-	-0-	-0-	-0-	49,800	1.79
Teton	-0-	-0-	-0-	-0-	-0-	-0-	61,500	2.04
Treasure	900	15.8	-0-	-0-	3,870	22.7	10,900	1.62
Wheatland	-0-	-0-	-0-	-0-	-0-	-0-	39,500	1.21
Yellowstone	1,400	15.8	-0-	-0-	12,490	20.8	26,600	2.53

1 - Acres harvested
2 - Yield per acre--bushels
3 - Irrigated silage only
4 - Yield per acre--tons
5 - Yield per acre--100 pound bags (cleaned)
6 - Yield per acre--Cwt (hundred weight)

SOURCE: Montana Crop and Livestock Reporting Service 1972

TABLE 4

LIVESTOCK PRODUCTION, 1971

Number of Head

County	Cattle	Sheep	Hogs
Beaverhead	166,000	86,000	3,400
Big Horn	125,000	10,500	11,900
Broadwater	39,000	7,000	1,300
Carbon	61,000	50,000	8,100
Cascade	96,000	18,000	3,000
Choteau	75,000	4,500	8,500
Deer Lodge	13,000	2,400	600
Fergus	124,000	20,000	19,000
Flathead	36,000	2,500	14,200
Gallatin	80,000	17,000	6,000
Golden Valley	31,000	10,000	2,400
Granite	37,000	2,600	100
Jefferson	25,000	3,000	1,200
Judith Basin	68,000	13,000	2,900
Lake	72,000	7,000	7,500

TABLE 4
(continued)

County	Cattle	Sheep	Hogs
Lewis & Clark	58,000	14,000	2,100
Madison	90,000	27,400	6,200
Meagher	53,000	15,000	1,300
Mineral	1,500	300	100
Missoula	21,000	1,400	1,900
Musselshell	42,000	18,000	2,300
Park	62,000	9,000	3,200
Powell	52,000	7,000	3,300
Ravalli	56,000	12,500	4,800
Rosebud	99,000	25,000	3,300
Sanders	30,000	2,000	700
Silver Bow	6,000	600	200
Stillwater	62,000	21, 00	14,100

TABLE 4
(continued)

County	Cattle	Sheep	Hogs
Sweet Grass	54,000	36,000	3,300
Teton	60,000	15,000	7,700
Treasure	33,000	4,000	1,400
Wheatland	46,000	32,000	1,800
Yellowstone	132,000	15,000	3,000

Source: Montana Crop and Livestock Reporting Service 1972

TABLE 5

SUBDIVIDED LAND (INCOMPLETE)

County	Acres Subdivided
Beaverhead	1867
Big Horn	661
Broadwater	151
Carbon	2621
Cascade	8459
Chouteau	*
Deer Lodge	1832
Fergus	1460
Flathead	56442
Gallatin	19999
Golden Valley	1204
Granite	3887
Jefferson	2866
Judith Basin	1460
Lake	9879
Lewis & Clark	10659
Madison	13475
Meagher	1402

SUBDIVIDED LAND (INCOMPLETE)
(continued)

County	Acres Subdivided
Mineral	2135
Missoula	40816
Musselshell	33031
Park	8051
Powell	6928
Ravalli	50267
Rosebud	454
Sanders	1398
Silver Bow	2129
Stillwater	8713
Sweet Grass	703
Teton	353
Treasure	*
Wheatland	*
Yellowstone	18647

Source: Environmental Information Center, 1974

* No information available

TABLE 6

MONTANA POWER SCHEDULED ELECTRIC TRANSMISSION LINES

	1974	1975	1976	1977	1978	1979
Anaconda-Hamilton 161 KV Line	ss	ss	xxxxx			
Mill Creek-Electric Furnace Arbiter 230 KV Line	xxxxx					
Clyde Park-Bozeman 161 KV "B" Line	ss	xxxxx				
Benchland-Glengarry 100 KV "B" Line	ss	xxxxx				
Chance-Belfry 50 KV Line		ss	xxxxx			
Clyde Park 161 KV Tie Line	ss	xxxxx				
Great Falls-Conrad 115 KV "B" Line				ss	xxxxx	
Clyde Park-Dillon Salmon 161 KV Line	ss	ssxxx	xxxxx			
Missoula-Hamilton 161 KV Line	xxxxx					
Ulm 100 KV Radial Line	ss	xxxxx				

s - Indicates date of survey work
x - Indicates date of construction

Source: MPC 1974

TABLE 7

HISTORICAL SPRINKLER IRRIGATION GROWTH IN MONTANA, 1968 - 1974

Year	H. P. Added	Total
1968		19,609
1969	2,081	21,690
1970	2,743	24,433
1971	4,643	29,076
1972	4,292	33,368
1973	9,619	42,987
1974	12,500	55,487 (est.)

Source: Montana Power Company 1974

TABLE 8

WILDERNESSES

Name	Total Acres	Approximate Acres In Study Area
Anaconda - Pintlar	158,516	39,000
Bob Marshall	950,000	750,000
Cabinet Mountains	94,272	94,272
Gates-of-the-Mountains	28,562	28,562
Scapegoat	239,936	239,936
Selway - Bitterroot	175,178	48,650

Source: U.S.F.S. 1974

TABLE 9

PRIMITIVE AREAS

Name	Administrative Agency	Total Acres	Approximate Acres In Study Area
Beartrap Canyon	BLM	3,639	3,639
Humbug Spires	BLM	7,041	7,041
Mission Mountains	USFS	72,177	72,177

Source: U.S.F.S.

TABLE 10

NEW STUDY AREAS

Name	Total Acres	Approximate Acres In Study Area
Abundance - Wolverine - Lost Creek	20,832	20,832
Arrastra - Stone Wall	9,400	9,400
Barb Mountain	52,000	28,800
Deep Creek	28,900	28,900
Dupuyer Creek	10,865	9,000
Flint Range	35,268	35,268
Gates-of-the -Mountains	6,000	6,000
Grizzly Basin	5,500	5,500
Hell Roaring - Buffalo Fork	71,606	71,606
Hoodoo	157,539	157,539
Lake Plateau	77,365	77,365
Maurice Mountain	36,625	1,000
Middle Fork - Continental Divide	302,700	302,700
North Absaroka	221,044	59,300
Renshaw Mountain	26,100	26,100
Silver King - Falls Creek	29,700	29,700
Swan Bunker	60,000	60,000
West Side Swan - Monture Creek	102,991	48,000

Source: U.S.F.S.

TABLE 11

NON-SELECTED ROADLESS AREAS

Name	Total Acres	Approximate Acres In Study Area
Baldy	7,100	7,100
Big Baldy	33,553	33,553
Birch Creek Basin	13,800	13,800
Black Bear	7,500	7,500
Black Canyon	5,000	5,000
Black Mountain	15,000	15,000
Blue Cloud	5,300	5,300
Boulder Mountain	22,180	22,180
Bowles Creek	7,731	7,731
Box Canyon	6,579	6,579
Brewster - Grizzly	17,500	17,500
Bridge Mountains	41,320	41,320
Bull & Black Mountains	8,760	8,760
Burdette Creek	15,740	15,740
Burnt Fork - Skalkaho Mountain	45,800	45,800
Carlton Creek - Big Creek	20,100	16,900
Castle Reef	15,162	15,162
Castles	24,601	24,601
Cliff Mountain Elect - Thunderbolt	5,760	5,760
Colorado	6,200	6,200
Copper Creek	9,770	5,100
Crazy Mountains	96,280	96,280
Crow Peak	2,867	2,867
Daly Roadbed	9,200	9,200
Deer Creek	18,000	18,000
Dry Range	15,355	15,355
Eagle Point - Dome Shaped Mountain	34,000	34,000

NON-SELECTED ROADLESS AREAS
(continued)

Name	Total Acres	Approximate Acres In Study Area
Elk Horn	6,170	6,170
Elk Creek	20,276	20,276
Haystack Mountain	10,368	10,368
High Woods	25,582	25,582
Hog back	17,262	17,262
Leavitt Creek - Ford Plateau	14,751	14,751
Little Blackfoot	18,000	18,000
Little Moose	7,000	7,000
Loco Mountain	24,371	24,371
Lolo Peak	17,000	17,000
Lower Arrastra - Stonewall	13,720	13,720
McClellan	16,500	16,500
Middle Fork	55,896	55,896
Middle Fork Judith	86,688	86,688
Middle Fork Teton	10,493	10,493
Mount High	31,368	31,368
Mount Werner	16,120	12,800
Nevada - South Poorman	23,360	23,360
North Copper - Silver King	14,540	14,540
North Siegal	9,400	9,400
Paine Gulch	5,683	5,683
Pat's Knob - North Cutoff	23,200	19,500
Petty Mountain	18,260	18,260
Pilgrim Creek	40,849	40,849
Quigg Peak	54,000	54,000
Ramshorn Mountain	10,400	7,900
Rattlesnake	59,325	59,325
Reservation Divide	20,700	20,700
St. Clair - Willow	10,500	10,500
Sandstorm Ridge	11,264	11,264

NON-SELECTED ROADLESS AREAS
(continued)

Name	Total Acres	Approximate Acres In Study Area
Sawmill Creek	9,643	9,643
Sawtooth	8,942	8,942
Silver King	17,664	17,664
Sleeping Child	25,100	21,100
Snow Bank - Keep Cool	2,520	2,520
Snowies	84,778	84,778
South Fork Dearborn	6,360	6,360
South Siegal - South Cutoff	17,840	12,200
Stark Mountain	17,210	17,210
Stemple Flesher	13,000	13,000
Stony Creek-Dome Shaped Mountain	15,334	15,334
Storm Lake	8,588	8,588
Swan Range	118,074	38,400
Tenderfoot - Deep Creek	88,729	88,729
Thompson Peak	6,700	1,500
Thompson River	75,200	74,240
Tobacco Root - Jefferson - Hollow Top	2,662	2,662
Twin Buttes	15,200	15,200
Tyler - Harvey	3,000	3,000
Upper Beaver	18,120	18,120
Upper Crow	4,600	4,600
Upper Ross Fork	28,058	28,058
Upper Skalkaho	14,700	14,700
Whitetail - Bigfoot	14,362	14,362
Whitetail Peak	9,651	9,651

Source: U.S.F.S.

TABLE 12

National Wildlife Refuges	Acres
Pablo	2,542
Ninepipe	2,022
Pishkun	8,195
Benton Lake	12,382
Ravalli	3,150
Hailstone	2,240
Lake Mason	18,173
Halfbreed Lake	3,096
National Bison Range	18,540

Source: U.S.B.S.F. & W.

TABLE 13

GAME MANAGEMENT AREAS

Name	Acres
Alberton	666
Beartooth	32318
Bitterroot	2136
Black Bluff	52
Blackfoot-Clearwater	49411
Bull Mountain	3552
Canyon Ferry	5000
Fairweather	4500
Flathead Lake	136
Fleecer Mountain	7302
Freezeout Lake	11349
Garrity Mountain	1760
Greycliff	605
Haymaker	1509
Isaac Homestead	1117
Judith River	4873
Moiese	80
Missouri Headwaters	523
Muddy Creek	680
Ninepipe	2755
Pablo	388
Pishkun Reservoir	1550
Pompey's Tower	94
Sun River	19775
Threemile	6049
Warm Springs	4445
Willow Creek Reservoir	1574

Source: Montana Fish and Game Department

TABLE 14
Agricultural Production For One Mile Of Corridor

County	Hay		Wheat		Corn	
	1971 Tons/ Acre	Tons/ Mile[1]	1971 Bushels/ Acre	Bushels/ Mile[1]	1971 Tons/ Acre	Tons/ Mile[1]
Beaverhead	1.6	57.6	31.6	1,138	0	--
Big Horn	1.9	68.4	30.2	1,087	16	576
Broadwater	2.6	93.6	24.4	878	15	540
Carbon	2.2	79.2	29.2	1,051	19.5	702
Cascade	1.6	57.6	26.5	954	18.0	648
Choteau	1.2	43.2	30.4	1,094	14.0	504
Deer Lodge	2.1	75	45.0	1,620	0	0
Fergus	1.1	39.6	30.7	1,105	15.0	540
Flathead	2.2	79.2	49.1	1,767	18.0	648
Gallatin	2.2	79.2	34.7	1,249	16.0	576
Golden Valley	1.6	57.6	26.9	968	0	0
Granite	1.9	68.4	31.1	1,119	0	0
Jefferson	1.6	57.6	21.3	766.8	0	0
Judith Basin	1.2	43.2	26.1	939.6	0	0
Lake	2.05	75.6	42.6	1,533	16.0	576
Lewis & Clark	1.6	57.6	26.2	943	14.0	504
Madison	2.2	79.2	30.5	1,098	0	0
Meagher	1.4	50.4	27.8	1,000	0	0
Mineral	2.52	90	35.6	1,281	0	0
Missoula	2.3	82.8	32.9	1,184	18.0	648
Musselshell	1.3	46.8	24.8	892.8	16.0	576
Park	2.1	75	29.7	1,069	18.0	648
Powell	1.82	65.5	40.4	1,454	0	0
Ravalli	2.9	104	37.5	1,350	17.0	612
Rosebud	1.8	64.8	28.2	1,015	15.0	540

TABLE 14 (Cont.)
Agricultural Production For One Mile Of Corridor

	Hay		Wheat		Corn	
County	1971 Tons/ Acre	Tons/ Mile[1]	1971 Bushels/ Acre	Bushels/ Mile[1]	1971 Tons/ Acre	Tons/ Mile[1]
Sanders	1.9	68.4	30.2	1,087	0	0
Silver Bow	1.9	68.4	--	--	0	0
Stillwater	1.4	50.4	26.9	968	18.5	666
Sweet Grass	1.8	64.8	24.4	878	0	0
Teton	2.0	72	30.9	1,112	0	0
Treasure	1.6	57.6	30.6	1,101	18.0	648
Wheatland	1.2	43.2	25.2	907.2	0	0
Yellowstone	2.5	90	30.4	1,094	18.0	648

Source: Montana Crop and Livestock Reporting Service 1972

[1] The mile figure represents 36 acres of land, derived from the amount of land utilized by a corridor 300' wide and 1 mile long.

CREDITS

Policy Guidance and Final Approval:
Gary J. Wicks, Director, Department of Natural Resources and Conservation (DNR&C)

Project Direction and Methodology Development:
Albert C. Tsao, Administrator, Energy Planning Division (EPD) DNR&C

Report Editing and Coordination:
Gail Kuntz, Report Coordinator, EPD

Editing:
David Lambert, Assistant Editor, EPD
Carole Massman, Special Staff, DNR&C
Frank Culver, Special Staff, DNR&C

Alternative Transmission Technology:
Krishna Shah, Transmission Engineer, EPD

Other Contributors:
Caleb H. Didriksen, Jr., Harza Engineering Company
James Keller, Harza Engineering Company
Peter Donalek, Harza Engineering Company
Stanley Anderson, Ph.D Professor, Electrical Engineering Department, Illinois Institute of Technology

Transmission Line Design Criteria and Specification Analysis:
Krishna Shah

Other Contributors:
Frank Mutch, Electrical Engineer, U. S. Forest Service
Daniel N. March, Ph.D Professor, Electronics Research Laboratory, M.S.U.
Robert Durnford, Ph.D Professor, Electrical Engineering Department, M.S.U.
William Q. Law, M.S.U.
George R. Wheatcroft, M.S.U.

Geological Inventory:
Brian White, Assistant Geologist, EPD
Lynn Brant, Geologist, EPD

Hydrological Inventory
Brian White

Soil Inventory
John Stanturf, Soil Research Assistant, EPD

Vegetation Inventory:
Lee Werth, Plant Ecologist, EPD

Assistants:
Donald Sorenson, Assistant Plant Ecologist, EPD
Leslie Haegen, EPD

Wildlife Inventory:
James A. Posewitz, Administrator, Environment and Information Division (EID), Department of Fish and Game (DFG)
Robert Martinka, Ph.D., EID, DFG
Peter Martin, DFG
James Wombaugh, DFG

Technical Editing:
Larry Thompson, Wildlife Ecologist, EPD

Meteorology Inventory:
Gerald Mueller, Meteorologist, EPD

Land Use Inventory:
Larry Thompson

Recreational Land Use Inventory:
Richard Mayer, DFG
Recreation and Parks Division Personnel, DFG

Technical Editing:
R. E. Cleary, Landscape Architect, EPD

Social Inventory:
John Fitzpatrick, Ph.D. Sociologist, EPD

Economic Inventory:
James M. Falvey, Ph.D. Economist, EPD

Impacts on Geology:
Brian White

Impacts on Hydrology:
Brian White

Impacts on Soil:
John Stanturf

Impacts on Vegetation:
Lee Werth

Assistants:
Donald Sorenson
Leslie Haegen

Impacts on Wildlife and Fisheries:
James A. Posewitz

Robert Martinka
Peter Martin
James Wombaugh

Technical Editing:
Larry Thompson

Impacts on Meteorology:
Gerald Mueller

Impacts on Existing Land Use:
R. E. Cleary

Impacts on Population and Social Factors;
State-Wide Public Opinion:
    John Fitzpatrick

Economic Impacts:
    James M. Falvey

Long-Term Impact Considerations:
    Lynn Brant

Public Involvement:
    Mike Moon, Information Assistant, EPD

Typing and Clerical Coordination:
    Sheri Unruh Davis, Division Secretary, EPD

Typing:
    Linda Stoll Beveridge
    Ann Danzer
    Kathy McGee
    Norma Smith
    Patricia Houghton
    Judy Hietala
    Lynn Hiatt

Maps, Drawings and Figures:
    D. R. Breiby, Chief of Cartography, DNR&C
    Cartography Bureau Personnel, DNR&C
    Morrison-Maierle, Inc.

All engineering studies supervised by Charles W. Greene, Montana P.E. No. 4177E.

ACKNOWLEDGEMENTS

Appreciation is extended to the following agencies and individuals for information and assistance provided:

U. S. Forest Service, Transmission Task Force:
- Earl Reinsel, Land Use Planner
- Ray Hunter, Land Use Planner
- Thomas Hagen, Landscape Architect
- William Schnelle, Transportation Planner
- Frank Mutch, Electrical Engineer

The following national forests:
- Beaverhead
- Bitterroot
- Custer
- Deerlodge
- Flathead
- Gallatin
- Helena
- Lewis & Clark
- Lolo

Centralized Services Division of the Department of Natural Resources and Conservation

Bonneville Power Administration

Department of State Lands

Bureau of Land Management

State Department of Highways

Bureau of Indian Affairs

Kenneth Coop, Wildlife Biologist, Department of Fish and Game

Shelly Fields, Bibliographer, EPD

Dr. Joseph R. Hatch, Geologist, Branch of Coal Resources, U. S. Geological Survey, Denver, Colorado

Terence Holst, Research Fellow, Montana State University

Harold Hunter, Woodland Conservationist, Soil Conservation Service

John Inman, District Ranger, Gallatin National Forest

Peter Jackson, Executive Secretary, Soil Conservation Districts

Paul Kipp, Forester, Bureau of Indian Affairs

Leon Logan, Hydrologist, Gallatin National Forest

Melvin S. Morris, Professor Emeritus, Range Management, University of Montana

Bud Nelson, Coordinator, Headwaters RC&D

Larry Pike, Billings District Forester, Department of Natural Resources and Conservation

Carl Ripaldi, Air Pollution Control Specialist in Vegetation

Craig Roberts, Forester, DNR&C

Robert Ross, Range Conservationist, Soil Conservation Service

Martha Spohn, Research Assistance, EPD

Jerry Stroebele, Biologist, Bureau of Sport Fisheries

Philip Tawney, Executive Director, Environmental Information Center

M. Bruce Tomko, Assistant Administrator, Transportation Division, Department of Public Service Regulation

Phillip Van Cleeve, Range Conservationist, Soil Conservation Service

Curt Wheeling, Chief, Communications Bureau, Department of Administration

Ted Wheetling, Communications Bureau, Department of Administration

Alternative Corridors